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Volume I

*Mission Design Data for Venus, Mars, and
Jupiter Through 1990*

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PREFACE

The work described in this report was performed by the Mission Analysis Division of the Jet Propulsion Laboratory.

This document is divided into three volumes. Volume I comprises the mission design data for Venus, Volume II the data for Mars, and Volume III the data for Jupiter.

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ABSTRACT

The purpose of this document is to provide a handbook, containing working data to be used in the selection and trajectory design of missions to Venus, Mars and Jupiter during the 1975-1990 time period.

MISSION DESIGN DATA FOR VENUS, MARS AND JUPITER THROUGH 1990

Andrey B. Sergeyevsky

A. INTRODUCTION

This document presents mission design data for direct transfer trajectories from Earth to three planets – Venus, Mars and Jupiter, extending previously published information (see Refs. 1, 2, 3, 4 and 5) through the 1990 departure opportunity.

The primary purpose of this effort is to provide the mission analyst with graphical information, sufficient for preliminary mission design and evaluation. The data follows closely the format of Reference 4 and reflects methods of Reference 2. A specially modified version of the Space Research Conic Program (SPARC) (see Ref. 6) was used to generate the trajectory information presented. The data were automatically contour-plotted on the SC4020 plotter using the General Plot Program (GPP) (see Ref. 7), then hand-retouched and labeled. A special program (VIEWPE) was constructed to provide planetary positional data in graphical form, plotted on the SC4020, and presented in original format.

The data are arranged in three sections by arrival planet, in natural sequence. Each section consists of two parts – the trajectory characteristics for all available opportunities to the particular planet, in chronological order, followed by that planet's positional data for every calendar year, from 1975 to 1995.

The persevering and encouraging insistence of management, especially that of Mr. Willard E. Bollman to carry this effort through to completion, as well as the graphic and editorial support of Mr. Richard W. Rackus are gratefully acknowledged.

B. DESCRIPTION OF TRAJECTORY CHARACTERISTICS DATA

1. General

The data represent trajectory performance information plotted in the departure date/arrival date space, thus

defining all possible transfer trajectories between the two bodies, within the time-span considered. Fourteen individual parameters are contour-plotted on the departure energy (C_3) background contour chart, for each opportunity. The following opportunities are presented:

To Venus: 1975, 1976/7, 1978, 1980, 1981, 1983, 1984/5, 1986, 1988, 1989/90.

To Mars: 1979, 1981/2, 1983/4, 1985/6, 1988, 1990.

To Jupiter: 1977, 1978, 1979, 1980/81, 1981/82, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990.

2. Definition of Terms

The following parameters are displayed on the contour plots:

C_3 Earth departure energy (km^2/sec^2); same as the square of departure hyperbolic excess velocity $V_\infty^2 = C_3 = V_I^2 - 2GM/R_I$, where

V_I = conic injection velocity (km/sec)

GM = gravitational constant times mass of the attracting body, from Reference 8:

$GM_{\text{VENUS}} = 0.32486010\text{E}6$
(km^3/sec^2)

$GM_{\text{EARTH}} = 0.39860115\text{E}6$

$GM_{\text{MARS}} = 0.42828444\text{E}5$

$GM_{\text{JUPITER}} = 0.12670772\text{E}9$

R_I	$= R_S + h_I$, Injection radius (km), sum of surface radius $R_{S\text{PLANET}}$ and injection altitude h_I , where (see Ref. 8):	DLA	Geocentric declination (vs. mean Earth equator of launch date) of the depar- ture V_∞ - vector. May impose launch constraints. (deg)
$R_{S\text{VENUS}}$	$= 6052$ (km)	ZAL	Angle between departure V_∞ vector and Sun-Earth vector. Equivalent to Earth- probe-Sun angle, several days out. (deg)
$R_{S\text{EARTH}}$	$= 6378.16$	INC	Heliocentric inclination of transfer tra- jectory with mean ecliptic (Earth orbital) plane of launch date. (deg)
$R_{S\text{MARS}}$	$= 3393.4$	ZAP	Angle between arrival V_∞ vector and the arrival planet-to-Sun vector. Equivalent to planet-probe-Sun angle at far encounter; for subsolar impact would be equal to 180° (deg).
$R_{S\text{JUPITER}}$	$= 71372$	ETS	Angle in arrival B-plane, measured from T-axis, clockwise, to projection of Sun- to-planet vector. Equivalent to solar occul- tation region center-line. (deg)
TF	Time of flight (Days)	LVI	Planetocentric latitude of vertical impact vs arrival planet equator. Note that Venus- ian north is below ecliptic, while Mars' and Jupiter's is above. Equivalent to declination of the incoming asymptote (i.e., the negative of incoming V_∞ vector) in planetary equator system.
CD	Earth to planet communication distance at arrival (km)	ZAE	Angle between arrival V_∞ vector and the planet-to-Earth vector. Equivalent to planet-probe-Earth angle at far encounter. (Deg.)
VHP	Arrival hyperbolic excess velocity $V_\infty = \sqrt{V^2 - \frac{2GM}{R}}, \text{ (km/sec),}$ where $V =$ Heliocentric conic arrival velocity at heliocentric radius R (km). Arrival Planet Orbit insertion velocity incre- ment ΔV , at periapse, may be computed from V_∞ : $\Delta V = \sqrt{V_\infty^2 + \frac{GM}{R_p}} - \sqrt{\frac{2GM R_A}{R_p(R_A + R_p)}}$ where R_p and R_A are planetocentric peri- apse and apoapse radii (km), respectively. Similarly, if specific capture orbit period P (sec) and periapse radius R_p are desired: $\Delta V = \sqrt{V^2 + \frac{2GM}{R_p}} - \sqrt{\frac{2GM}{R_p} - 3\left(\frac{2GM\pi}{P}\right)^2}$	ETE	Angle in arrival B-plane, measured from T-axis, clockwise, to projection of Earth- to-planet vector. Equivalent to Earth occultation region centerline. (deg)
B-PLANE	A plane normal to the incoming V_∞ - vector and passing through the center of planet.	THA	Angle in arrival B-plane, from T-axis, clockwise, to major axis of error dis- persion ellipse (0 - 180 deg).
T-AXIS	Axis in B-plane, parallel to ecliptic (Earth mean orbital) plane (see Figure 1).	SG1	Semi-major axis magnitude of B-plane dispersion ellipse, resulting from a spher- ically distributed V_∞ velocity vector error of 0.1 m/sec on departure asymptote (km).
		SG2	Semi-minor axis of above dispersion eclipse (km).

SG3 Arrival time dispersion, normal to B-plane,
for above error model (sec).

YR/M/D Year, Month, Date.

C. DESCRIPTION OF PLANETARY POSITIONAL DATA

1. General

The data represent planetary geometry-related information plotted versus calendar arrival date at the target planet. Each set of seven plots represents the annual time history of 19 parameters, and may be used for flyby and orbiter missions.

2. Description of Curve Labels

P	Target planet, equivalent to probe approaching or in orbit about target planet.
E	Earth
S	Sun
CA	Cone Angle, i.e., Sun-probe-object (Earth or Canopus, etc.) angle. (See Figure 2.)
KA	Clock Angle, i.e., angle between projections of the Probe-Canopus and probe-object vectors into the plane normal to the sun-line (for which CA = 90°). (See Figure 2.)
RISEXX	Rise time (GMT) of planet through 6° horizon mask at DSN Station No. XX. (e.g., XX = 14 = GOLDSTONE, 43 = CANBERRA, 63 = MADRID.)
SETXX	Set time (GMT) of planet through 6° horizon mask at DSN Station No. XX.

3. Description of Plots

Plot	Y-axis label	
a)	DECLIN	Geocentric Earth equatorial declination of planet (P), planetocentric planetary equatorial declination of Earth (E) and Sun (S). Note that Venusian north is below ecliptic.
b)	EC.LON	Heliocentric ecliptic longitude of planet.
c)	CA,KA	Cone (ECA) and Clock (EKA) angle of Earth and cone angle of Canopus (CCA) as seen from a Sun-Canopus oriented spacecraft near target planet, P (see Figure 2).
d)	DISTANCE	Sun-Planet distance (SP) and Earth-Planet communication distance (EP) in mill. km.
e)	SUN-EARTH-PLANET	Sun-Earth-Planet angle (SEP), indicating times of superior (SEP \approx 0) and inferior (SEP \approx 180°) conjunction; SEP > 5° is a communications constraint.
f)	STATION RISE/SET	Rise and Set times (GMT) of planet at 3 DSN Stations on Earth, 6° mask.

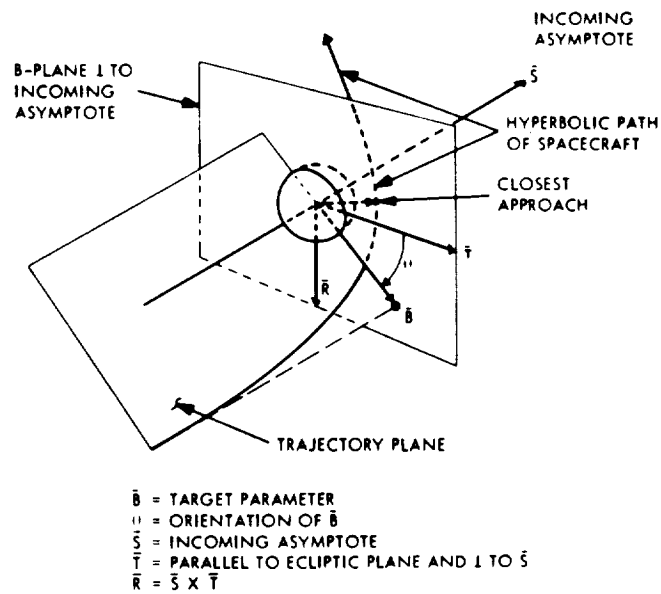


Figure 1. Definition of B-Plane

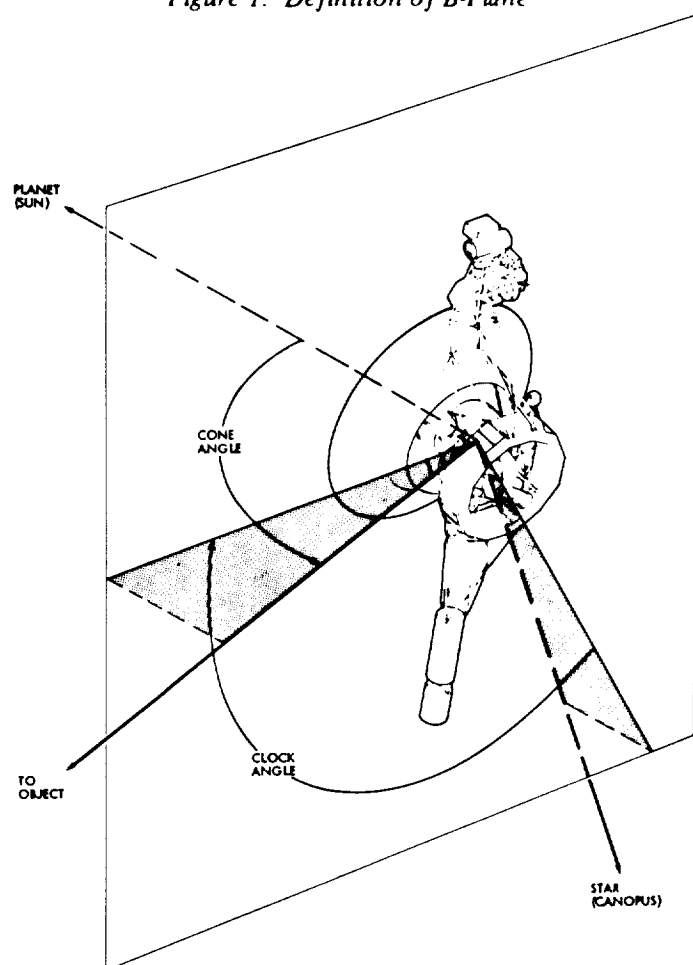
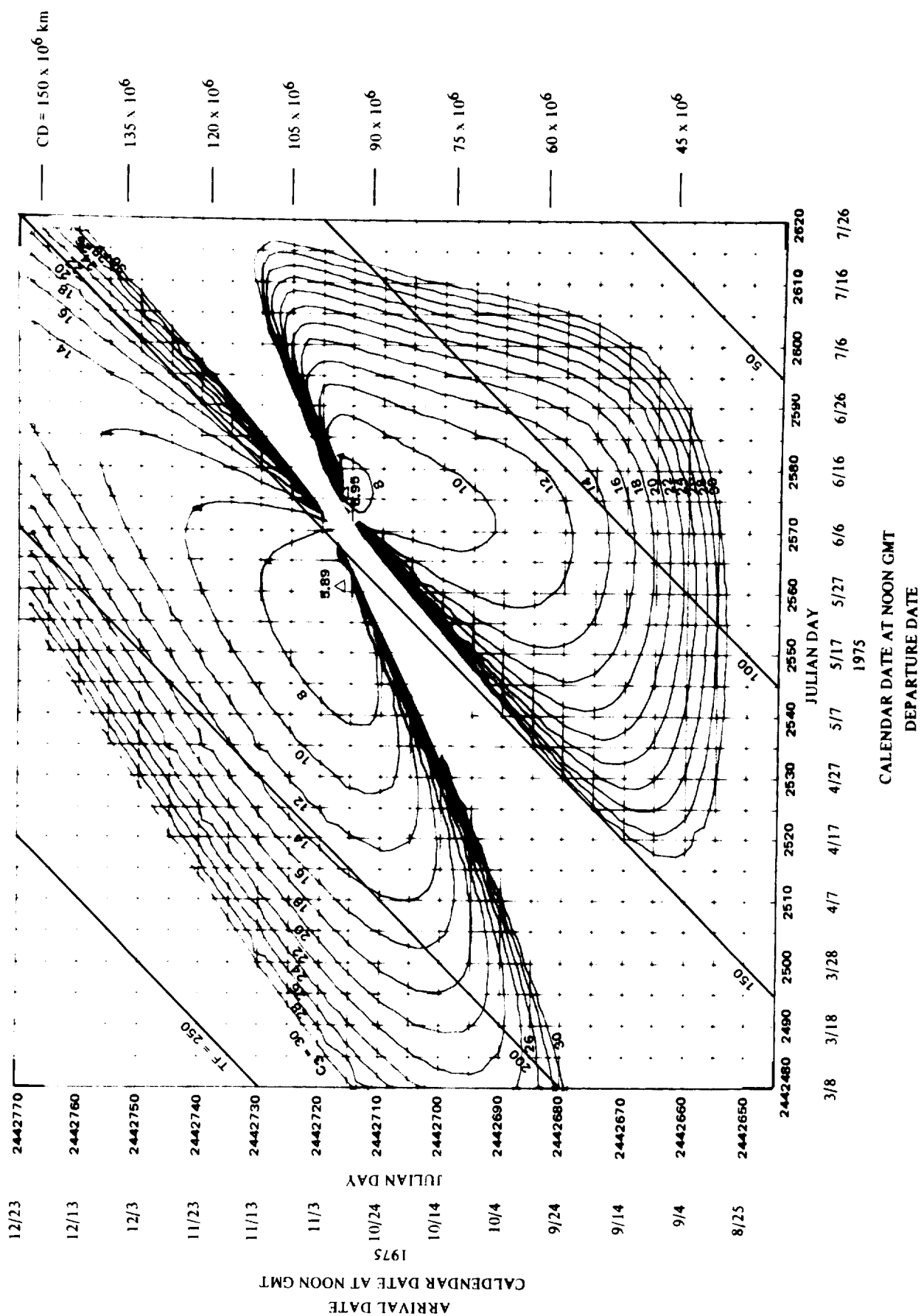


Figure 2. Definition of Cone and Clock Angle

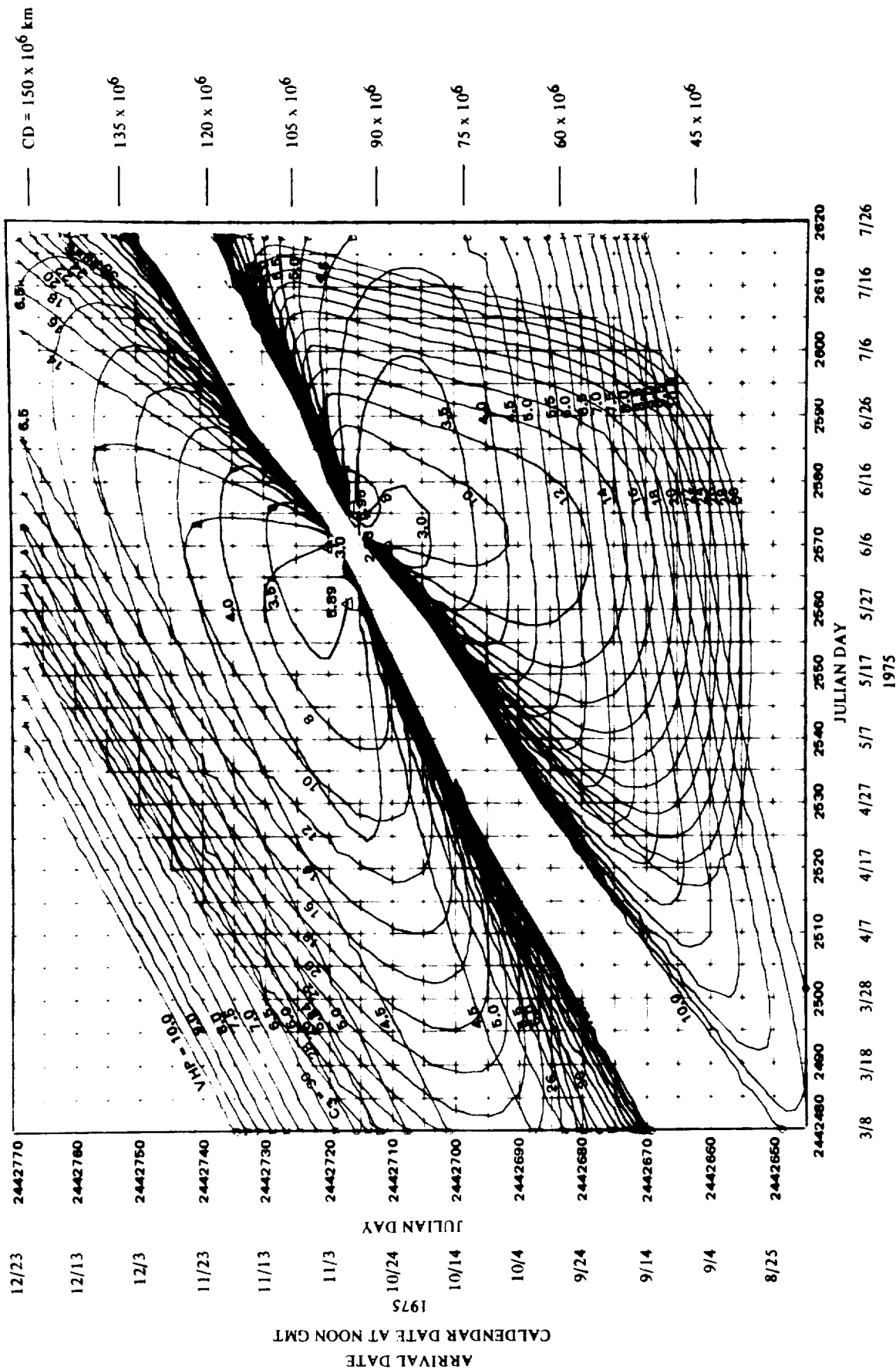
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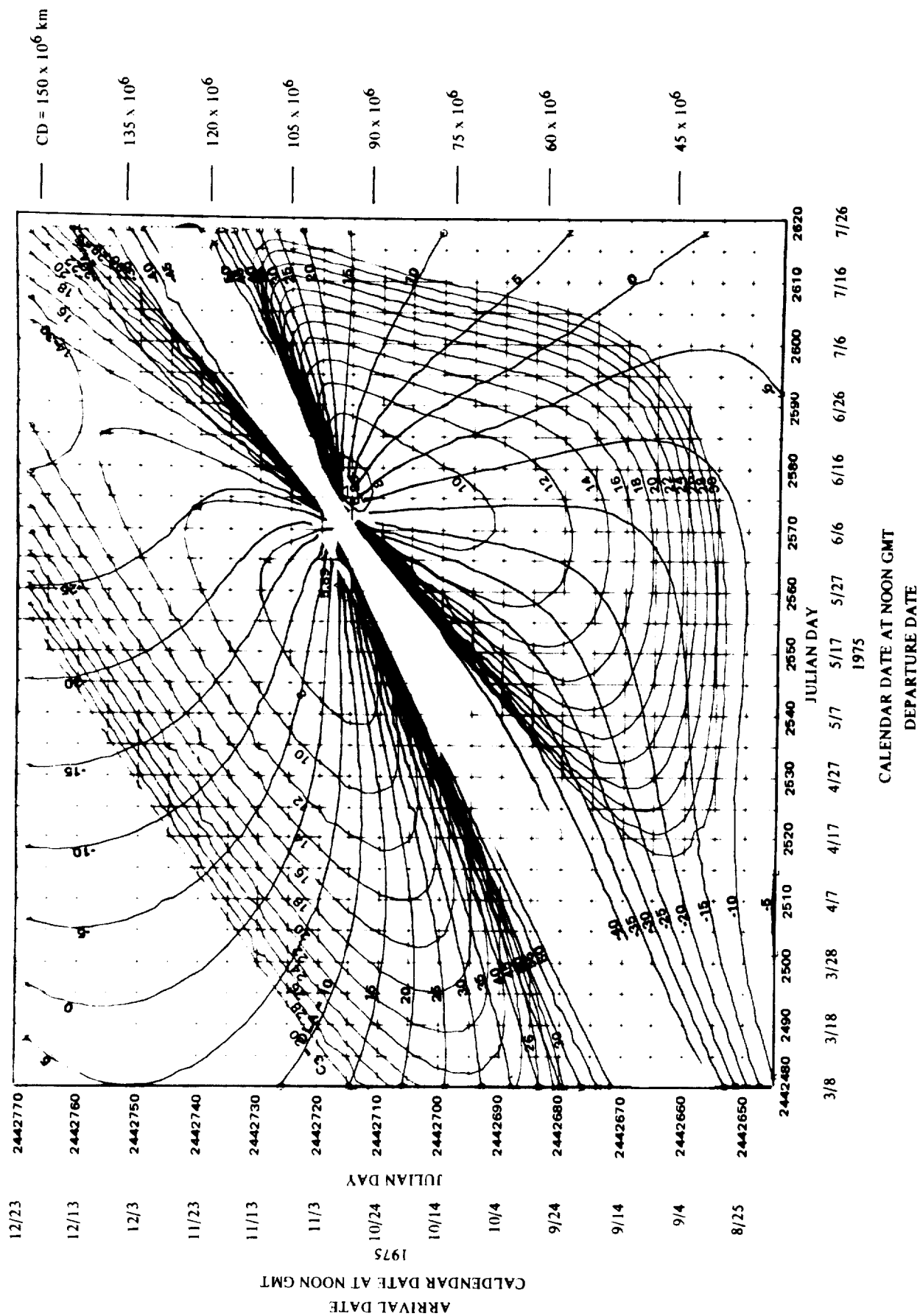
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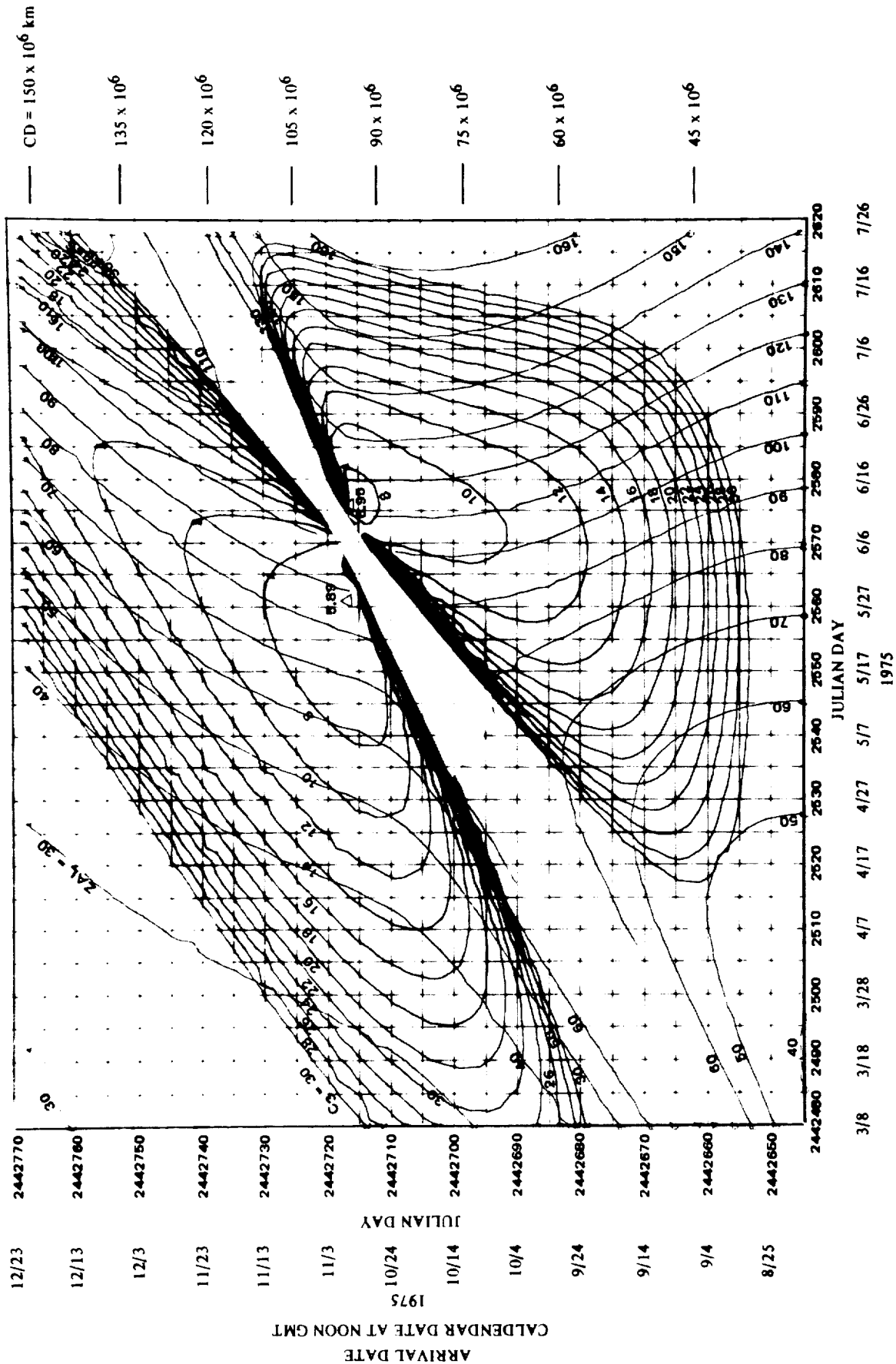


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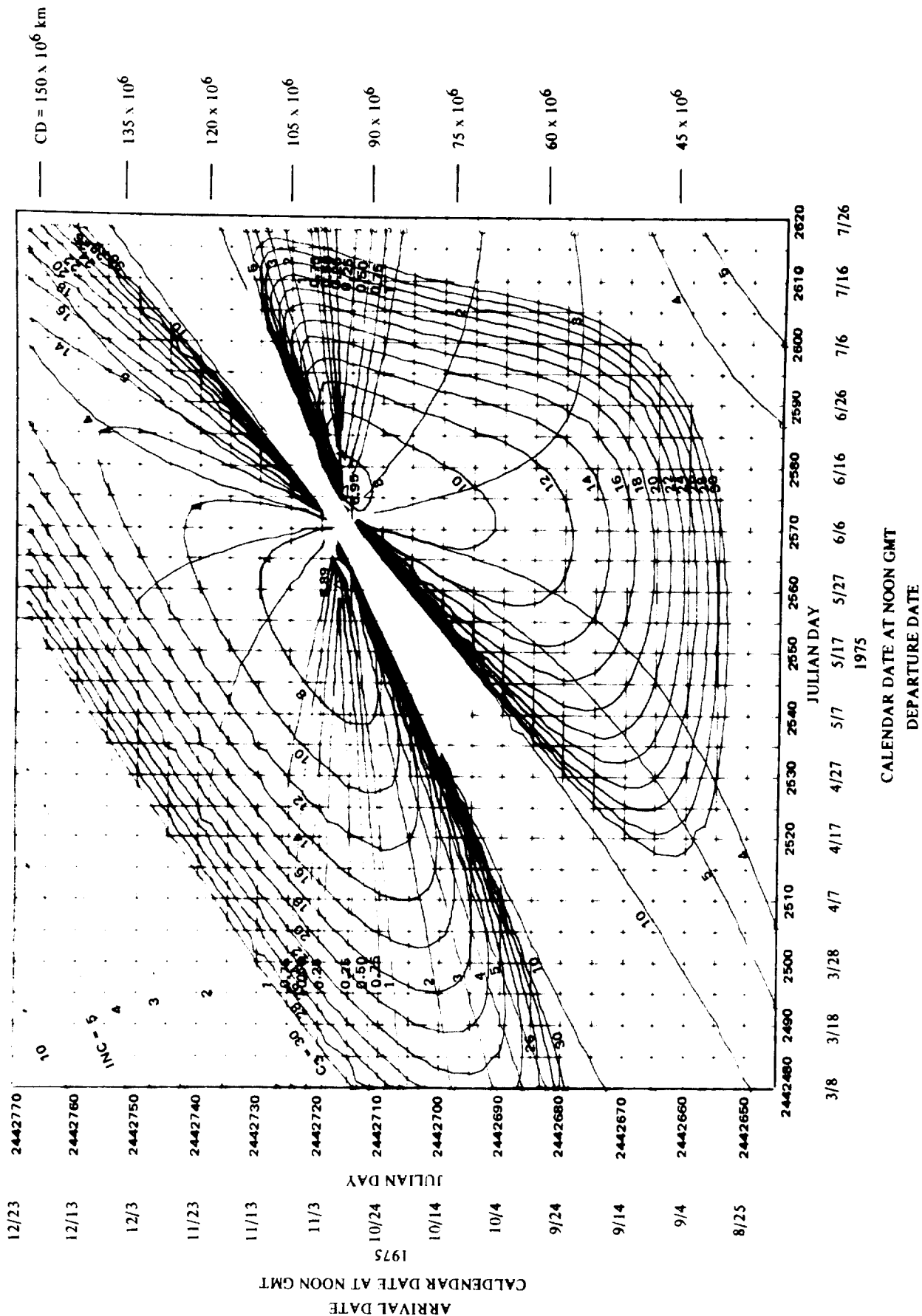


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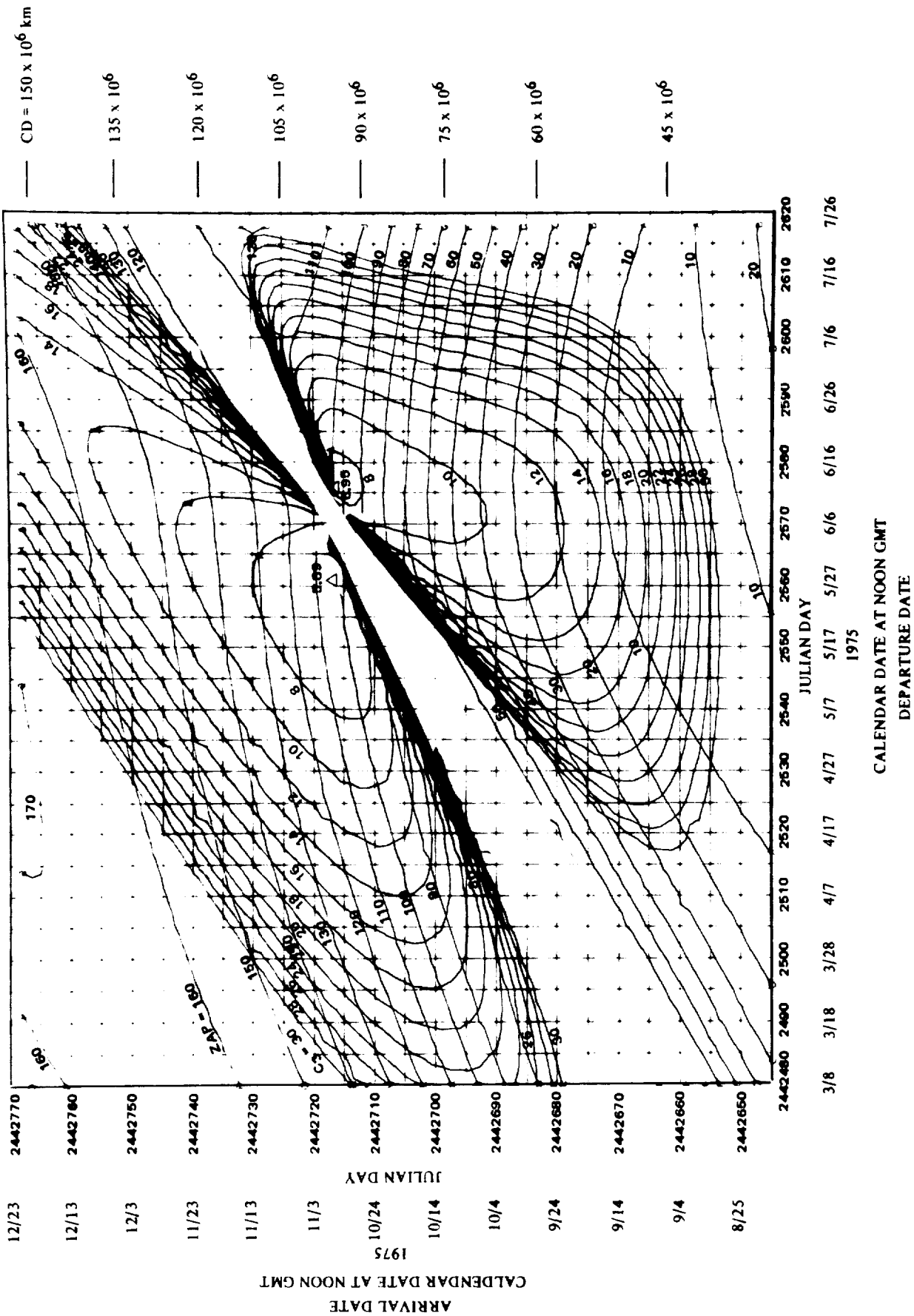




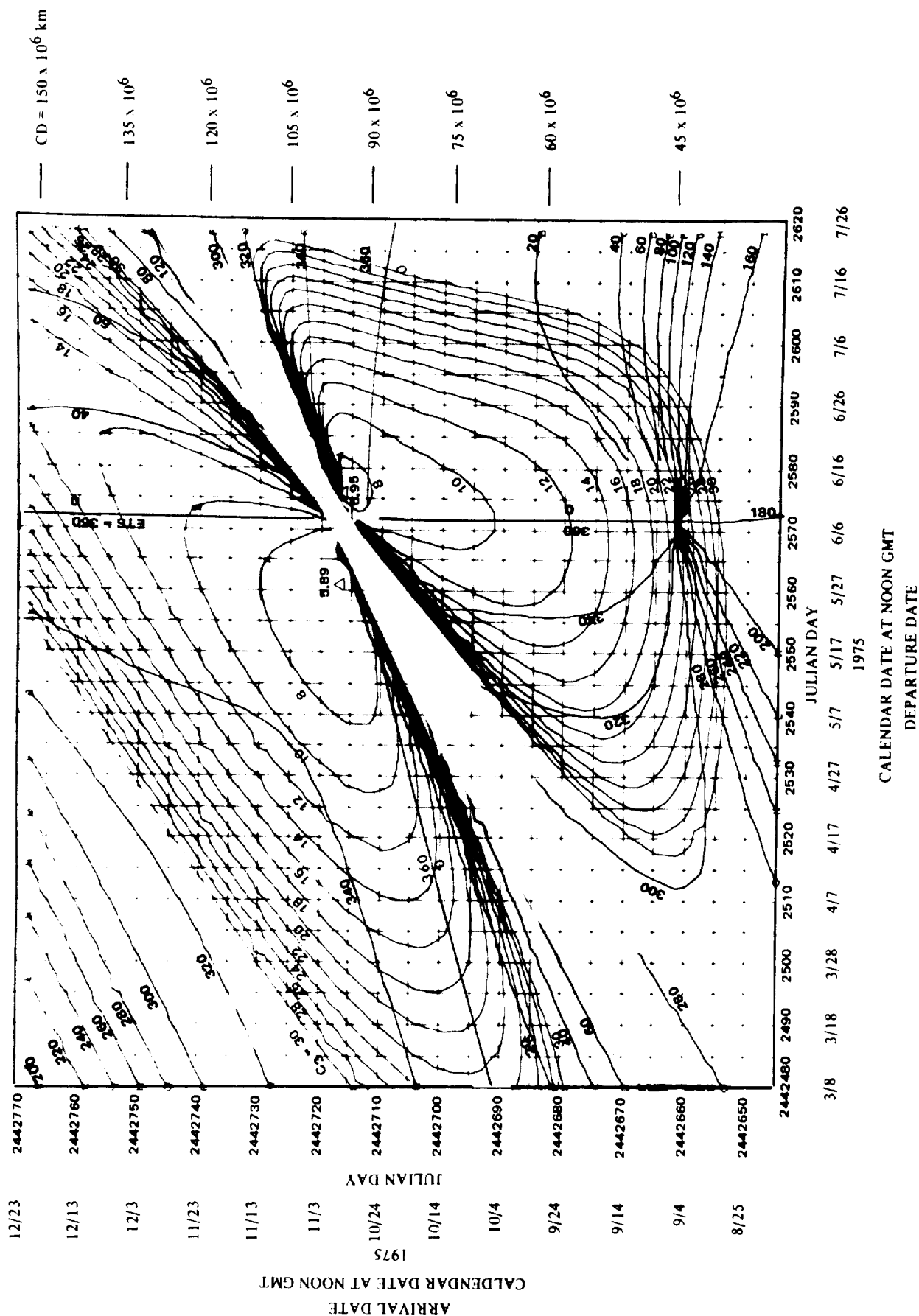
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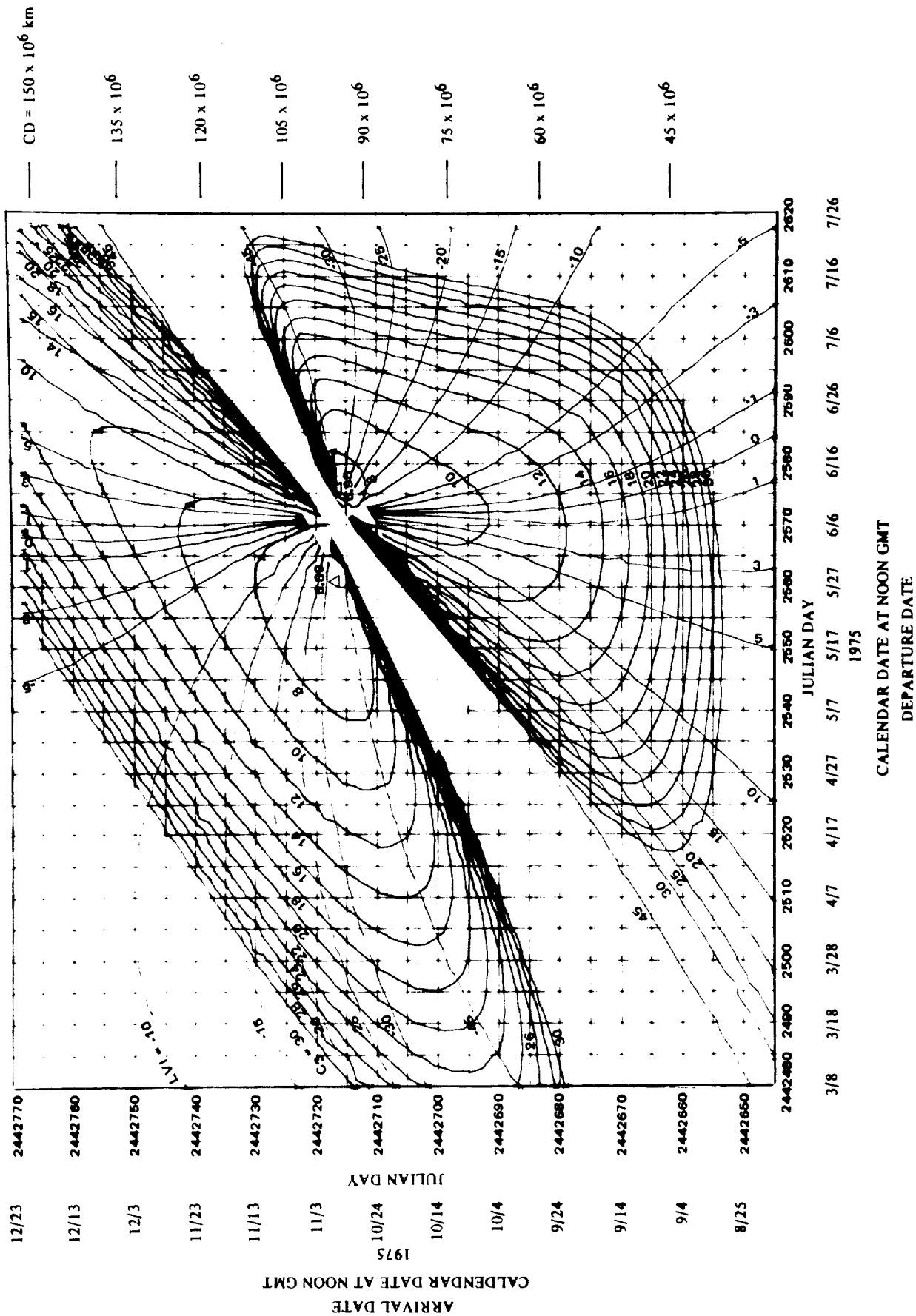
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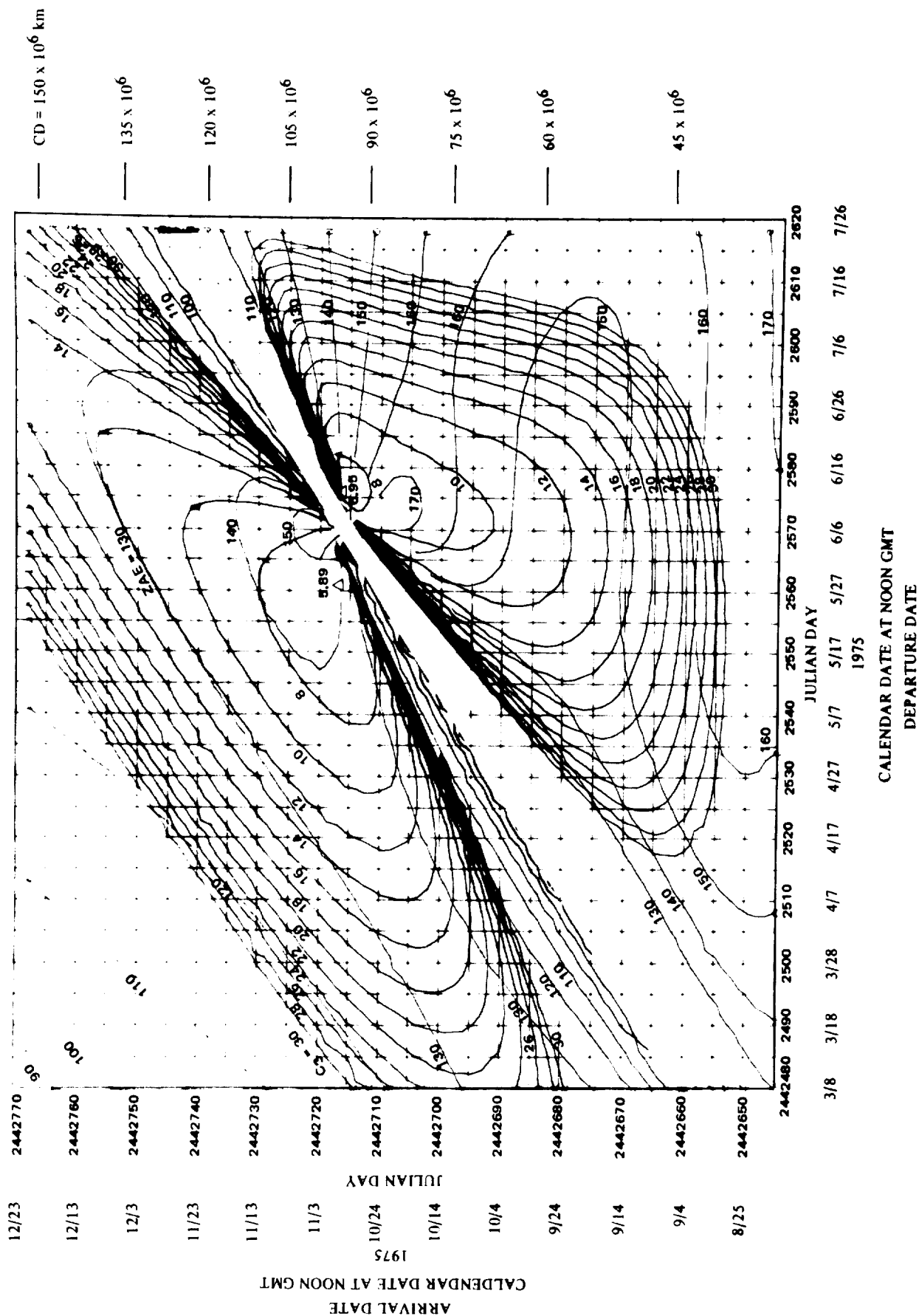
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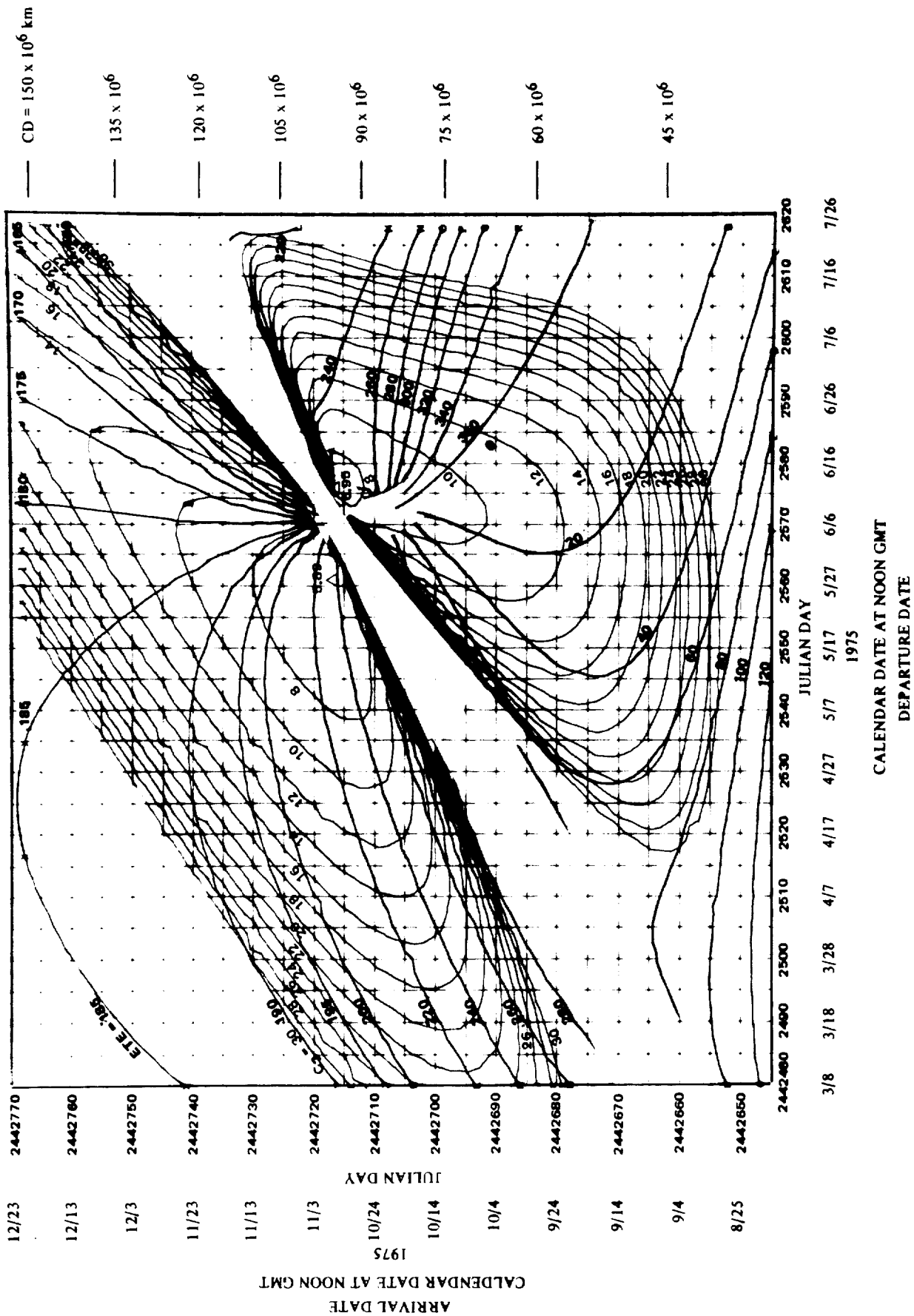
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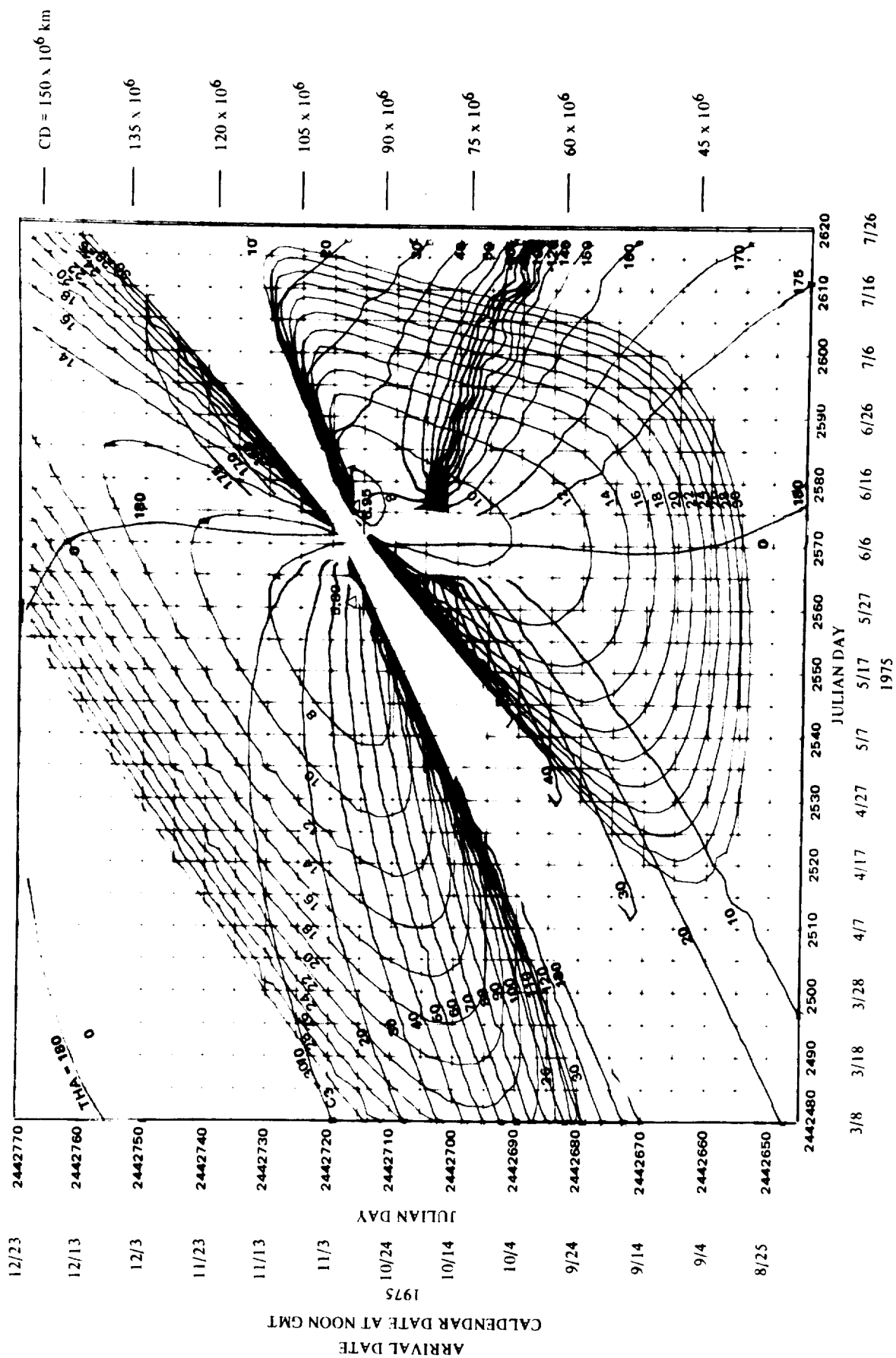
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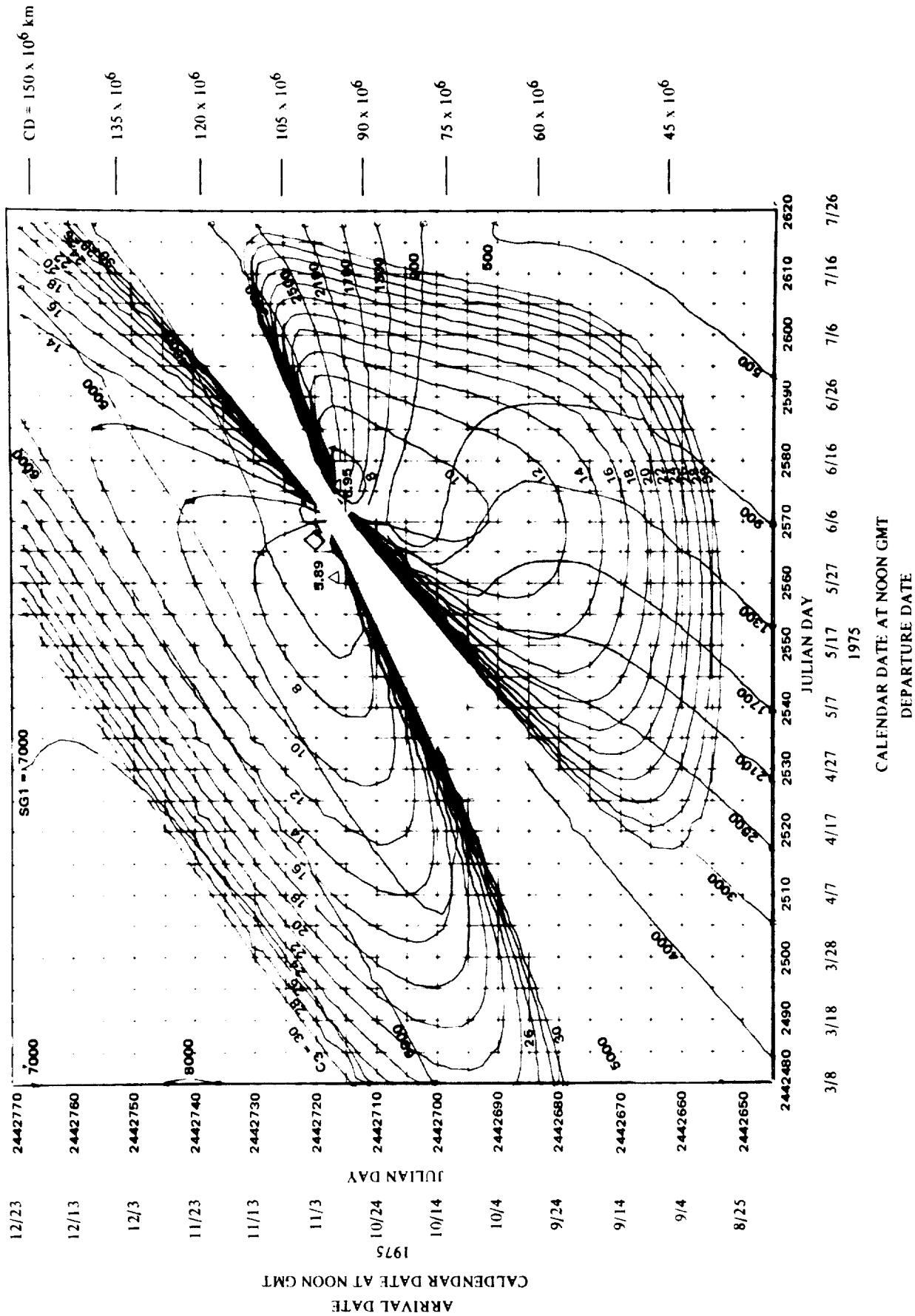
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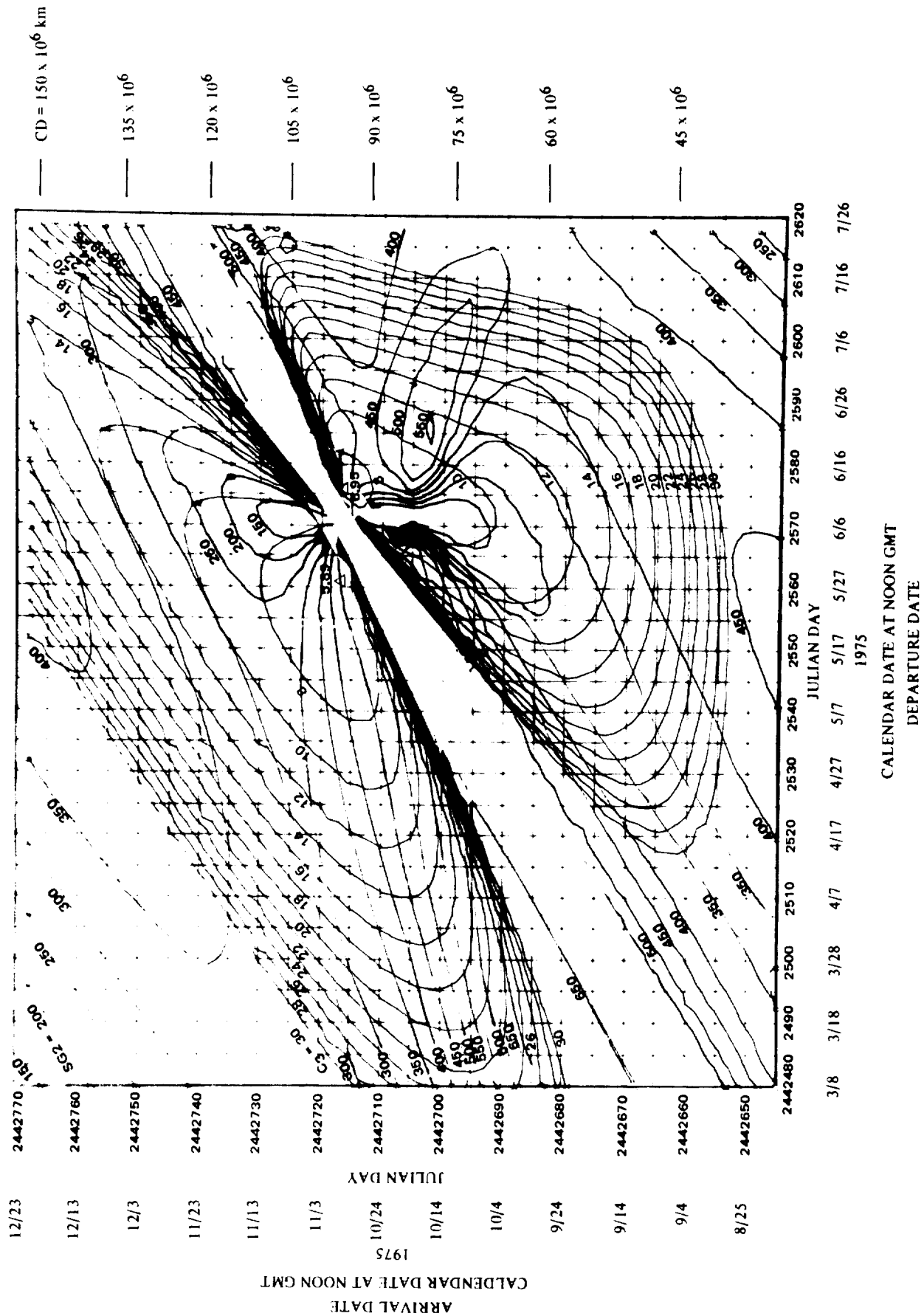
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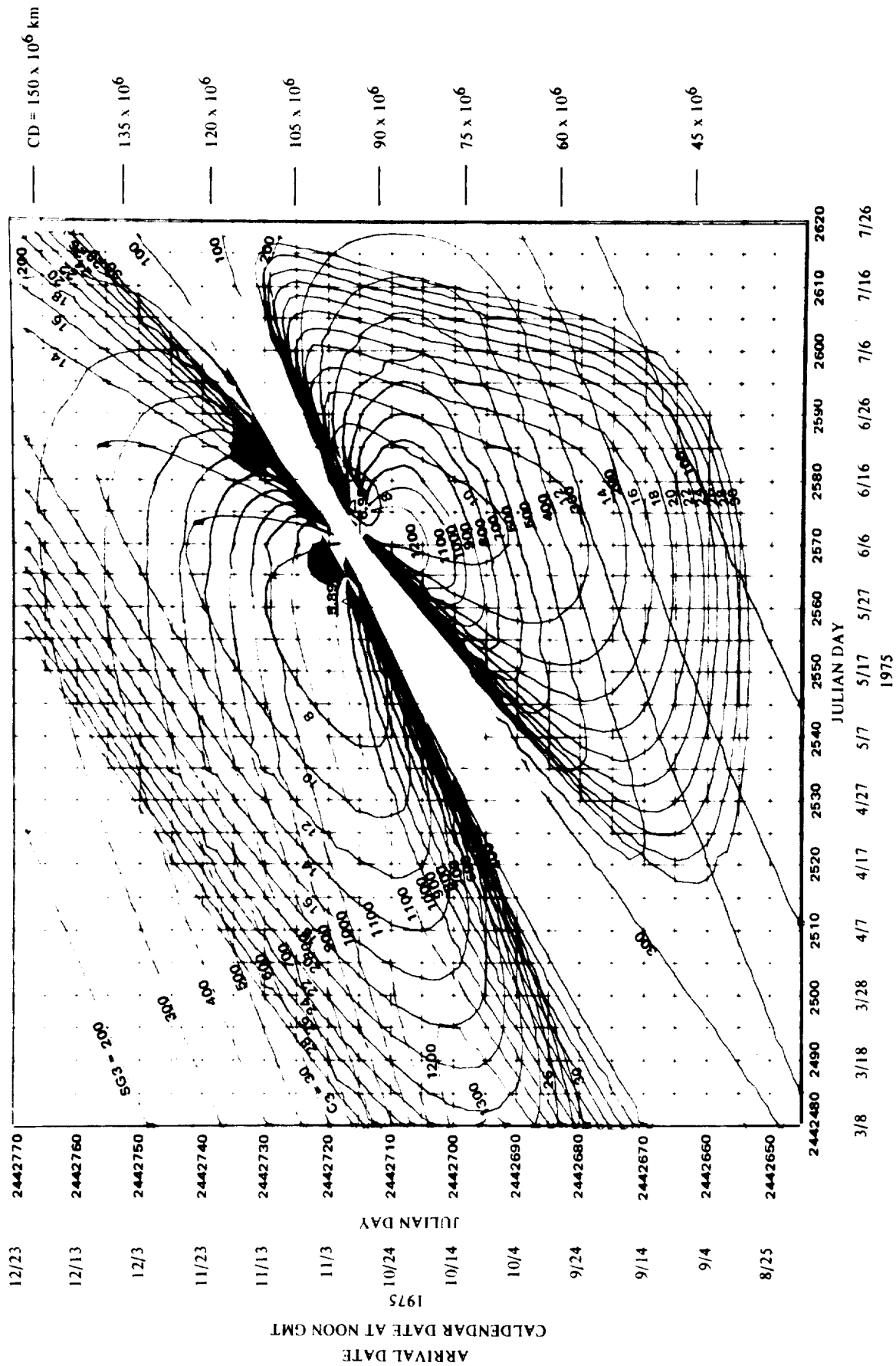
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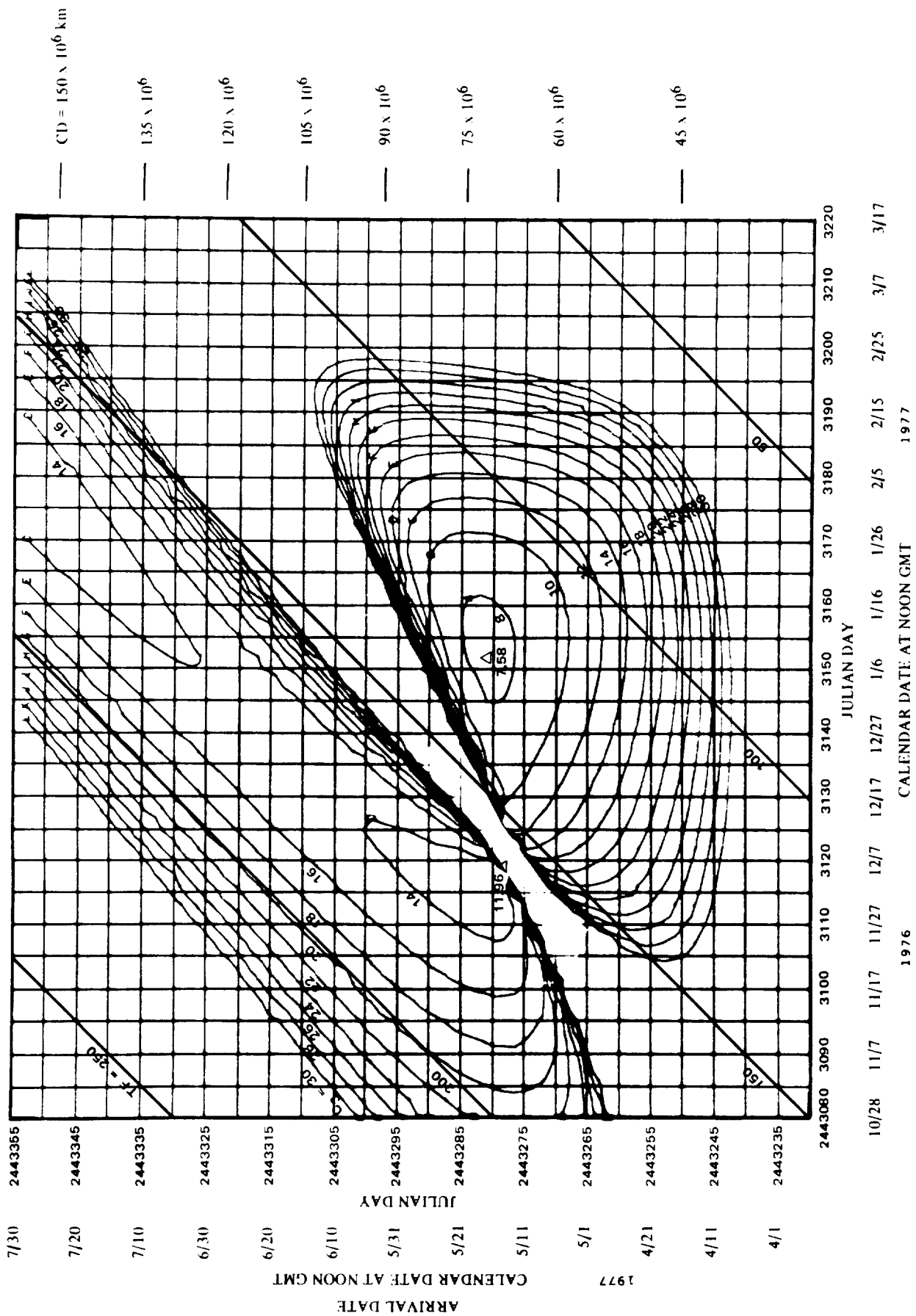
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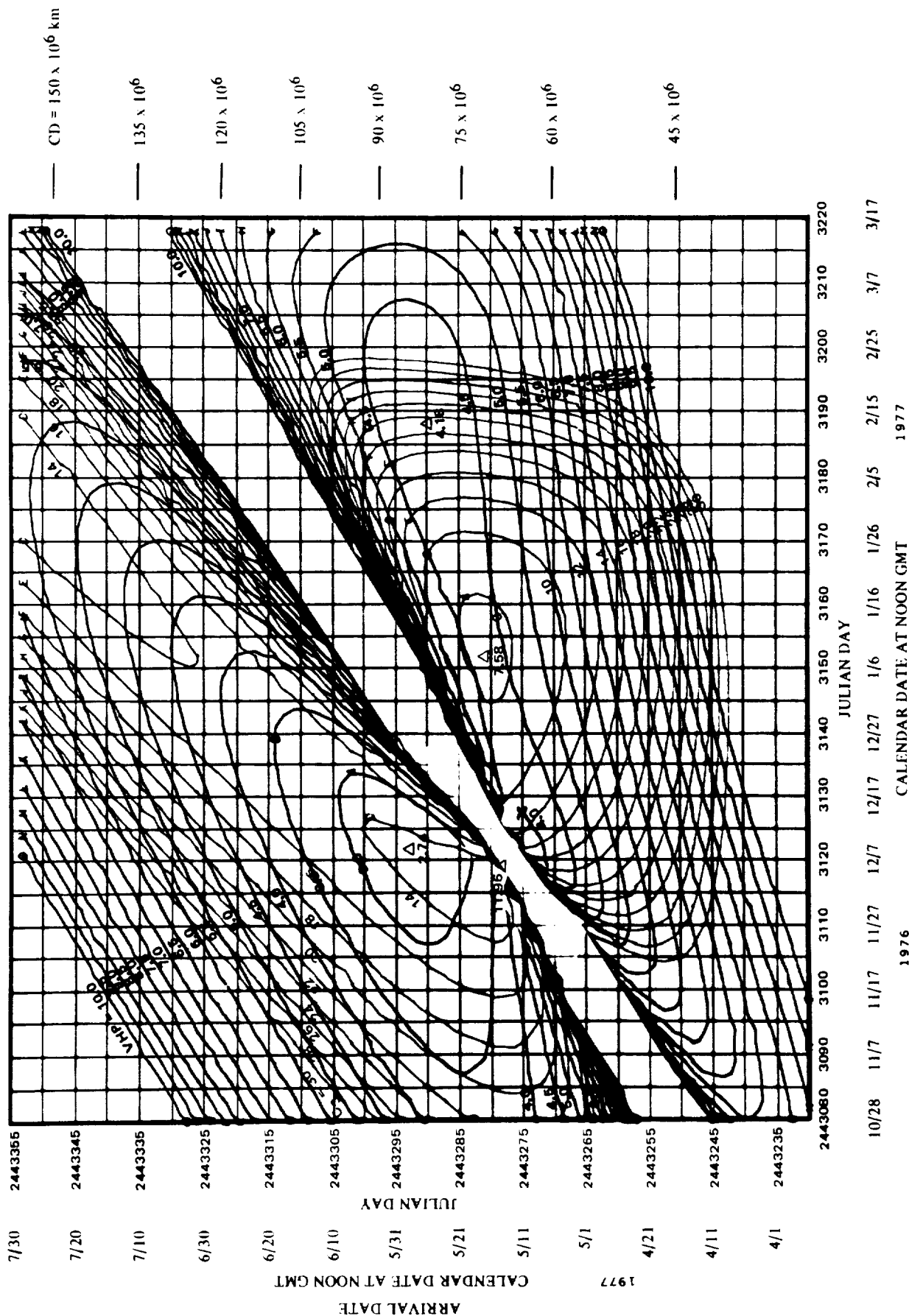
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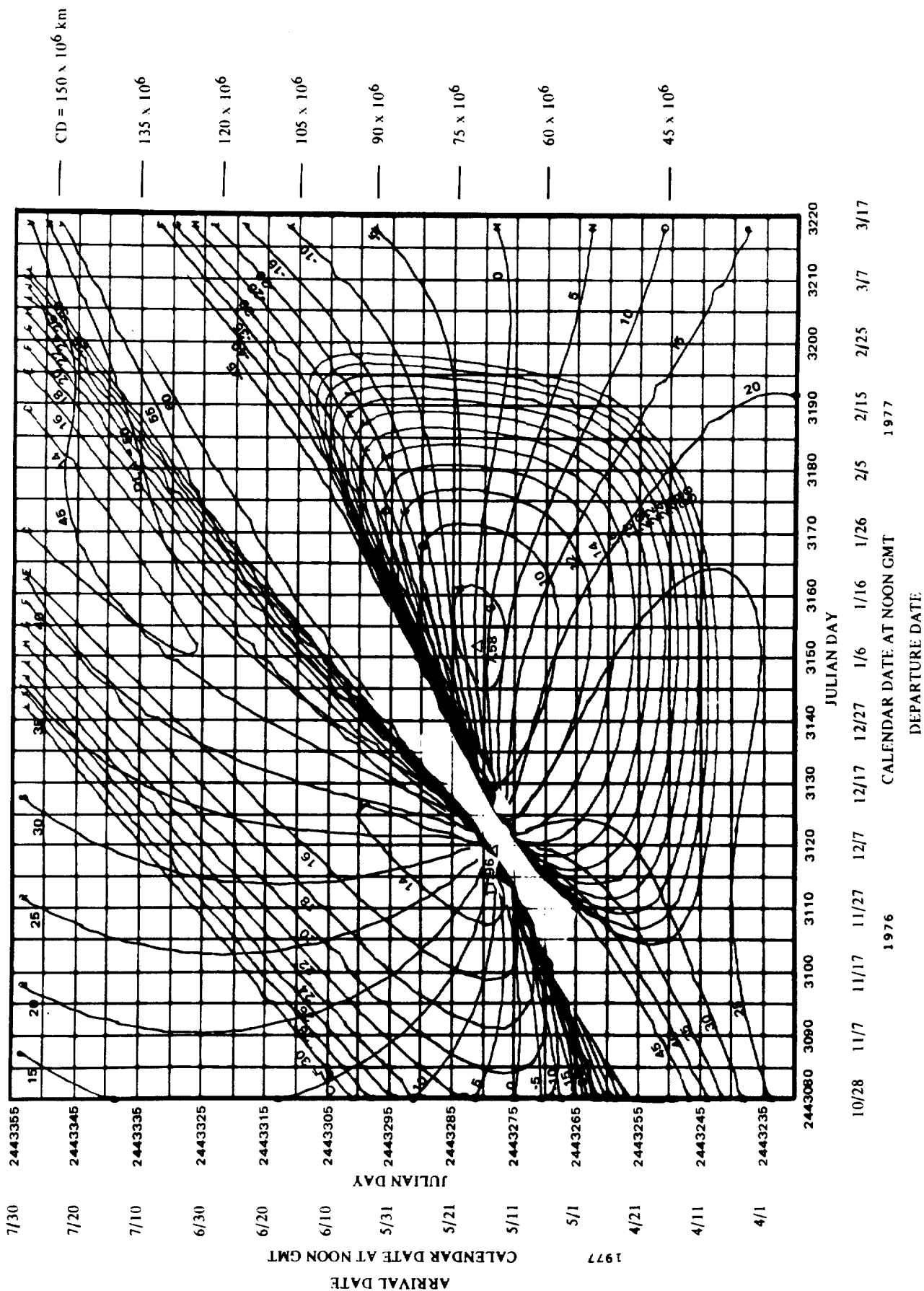


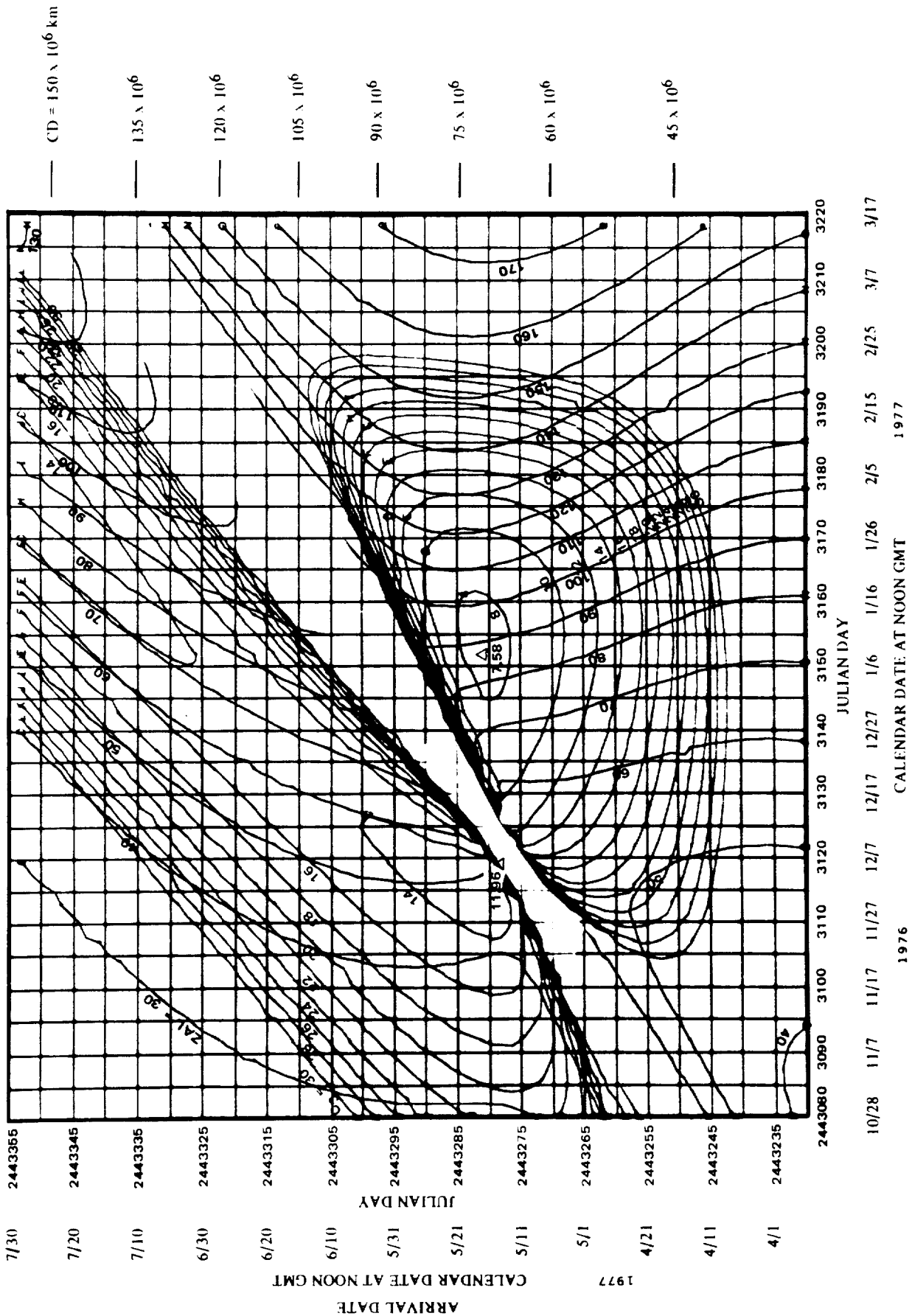
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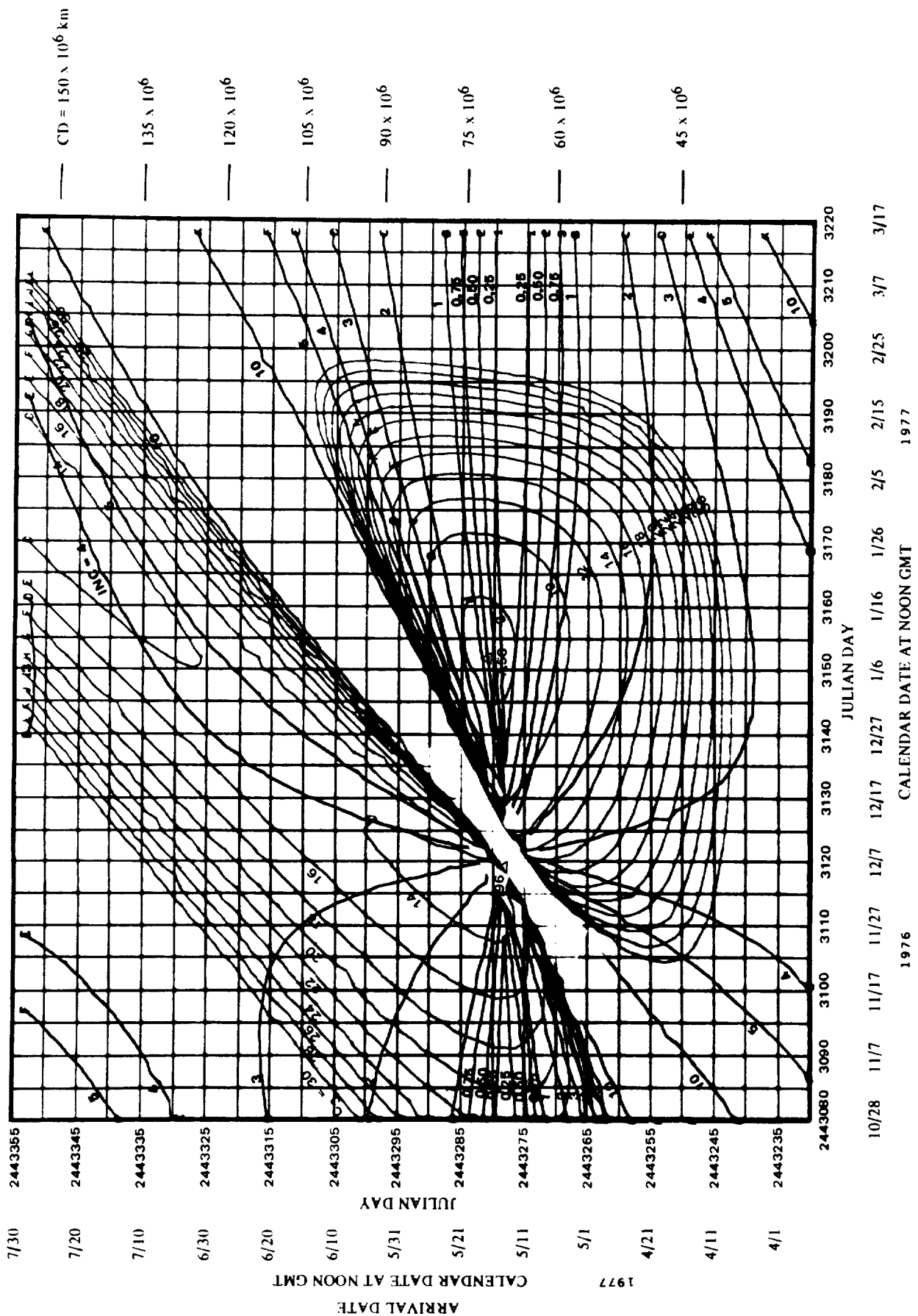
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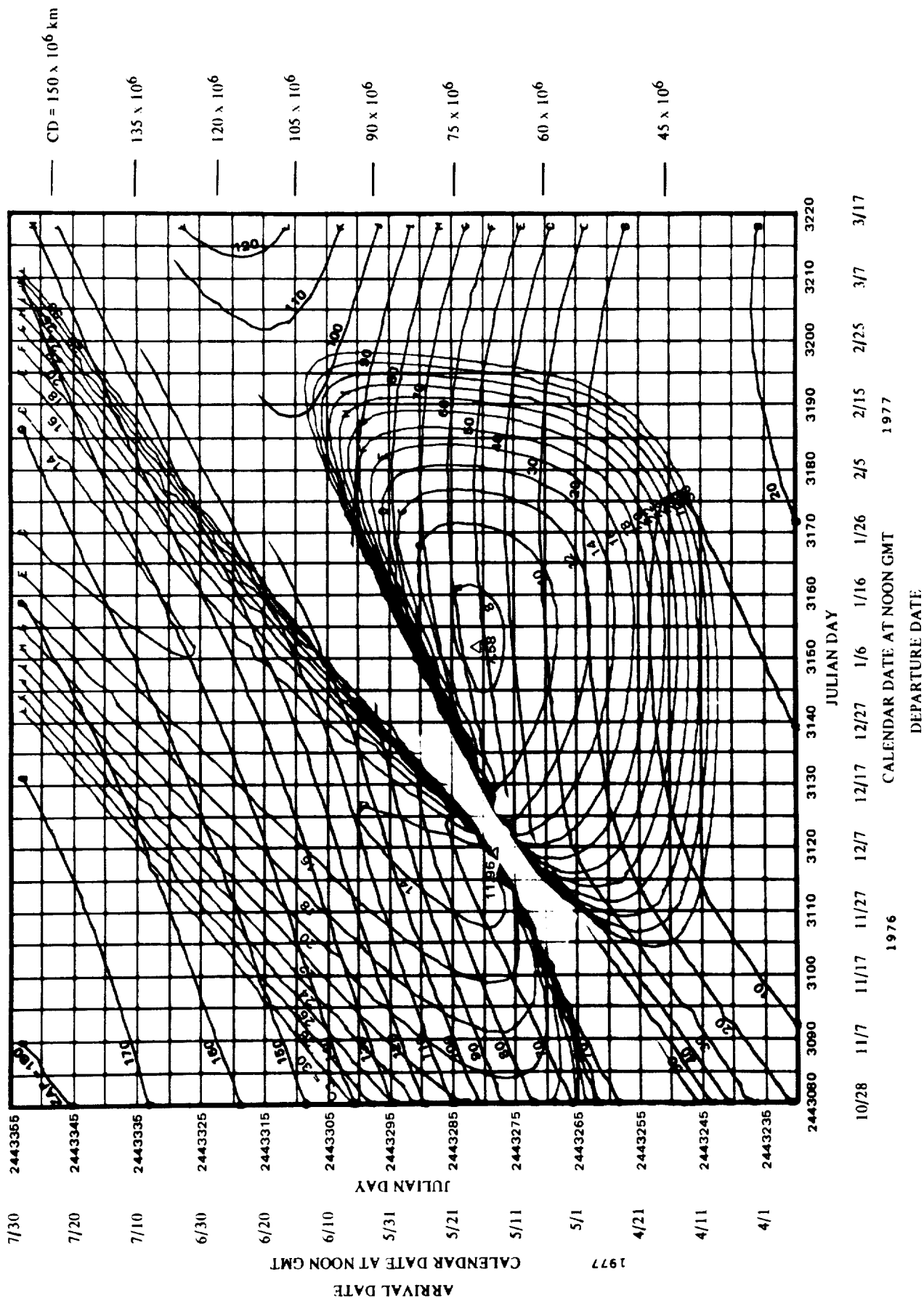




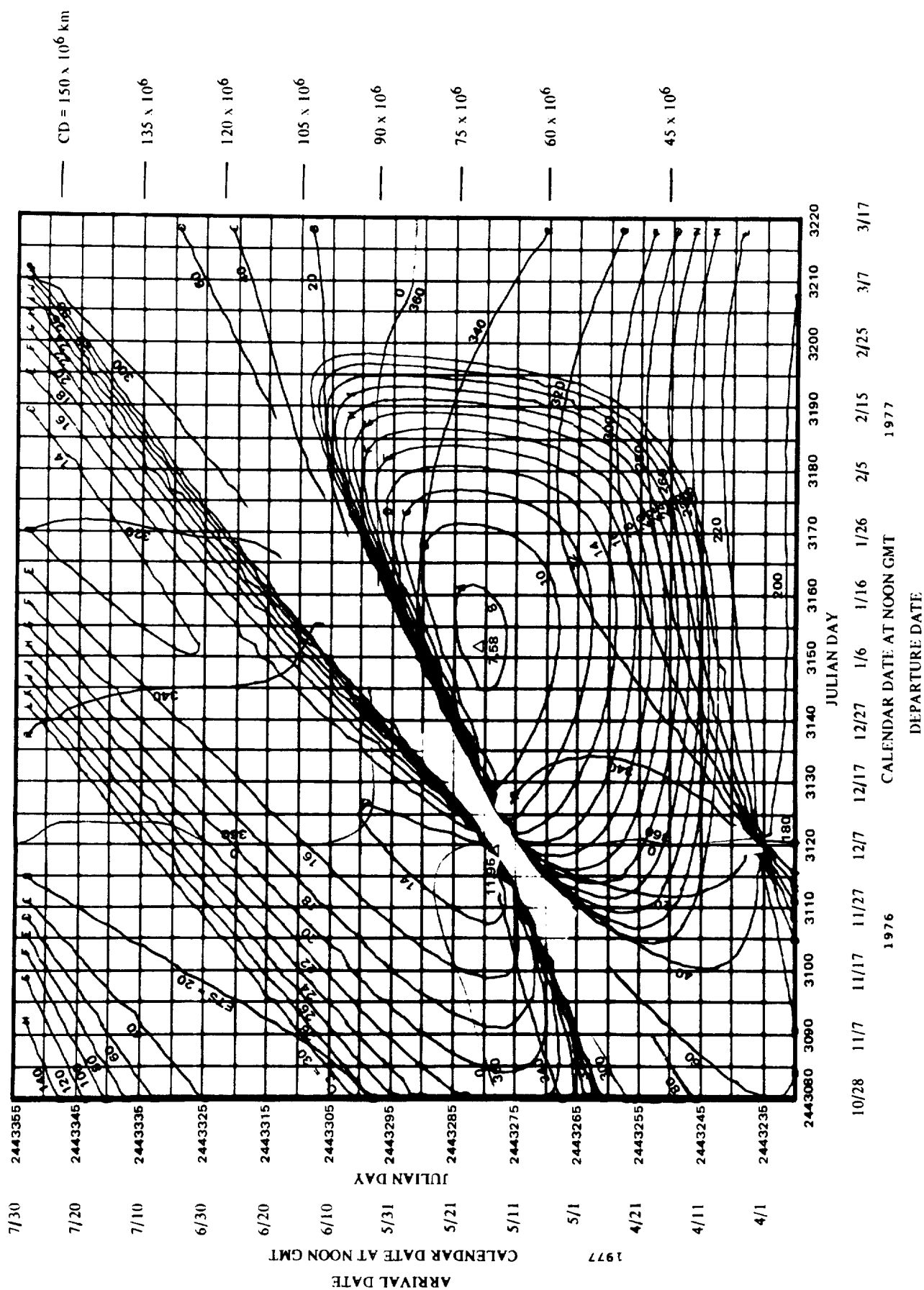
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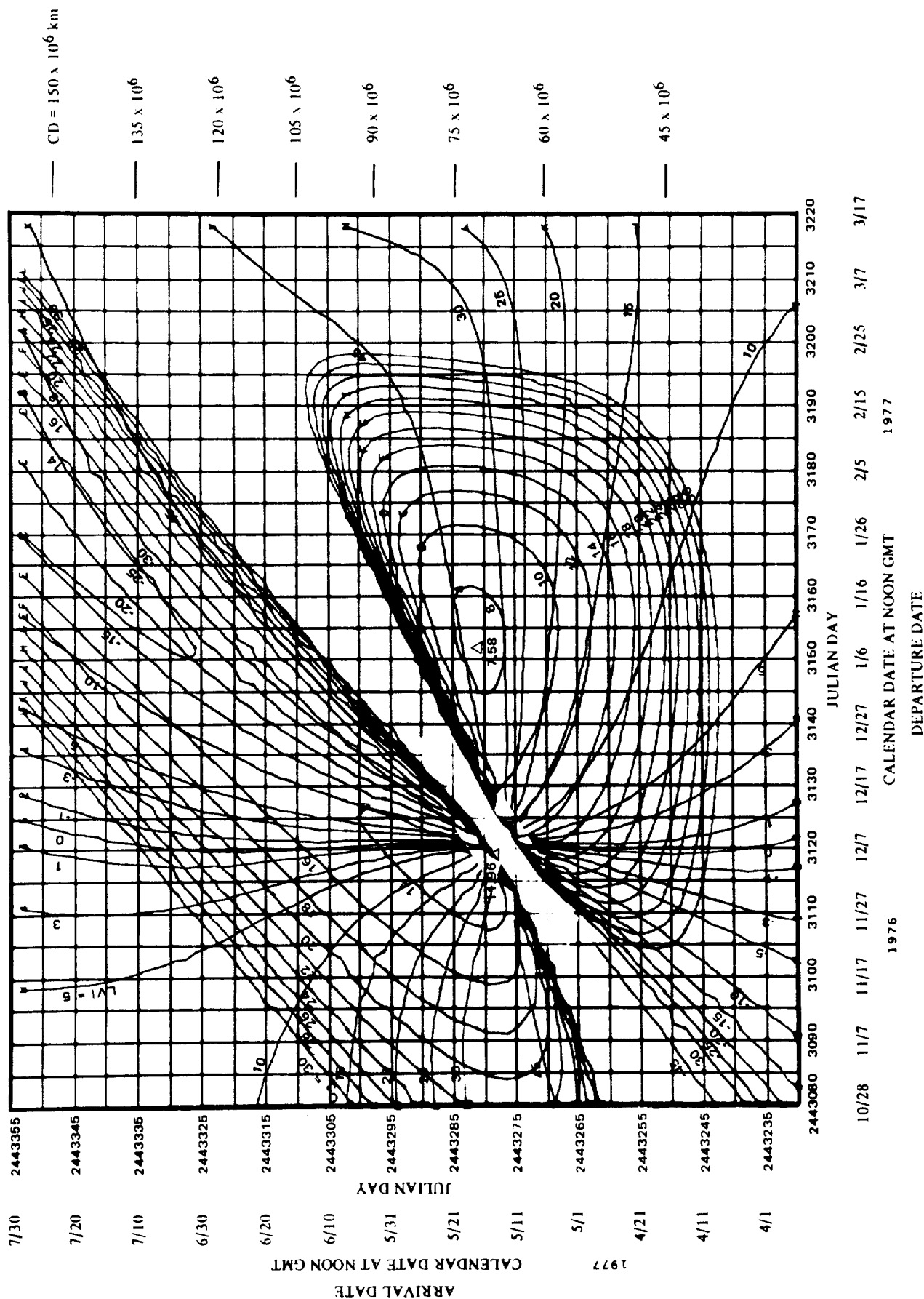
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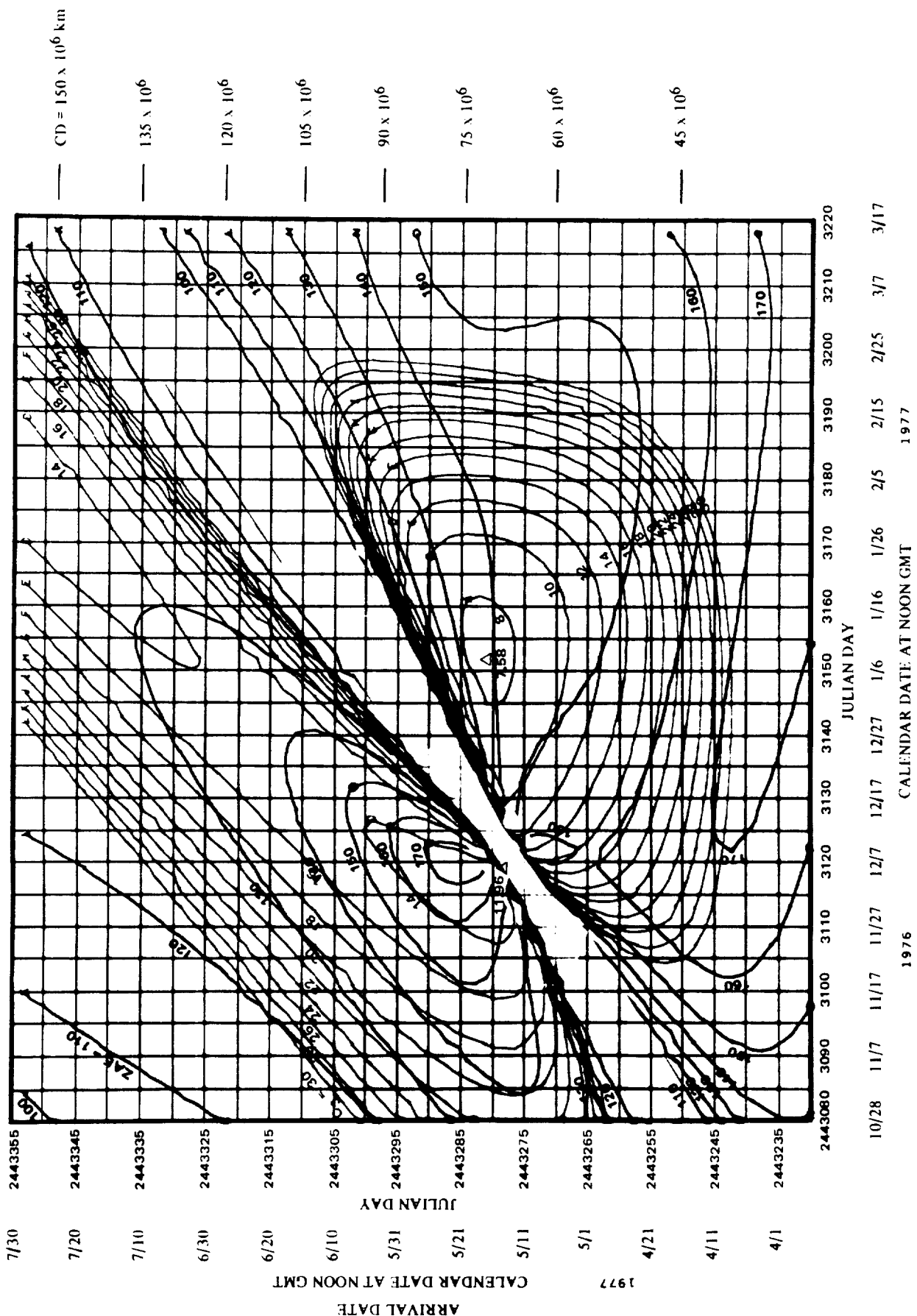
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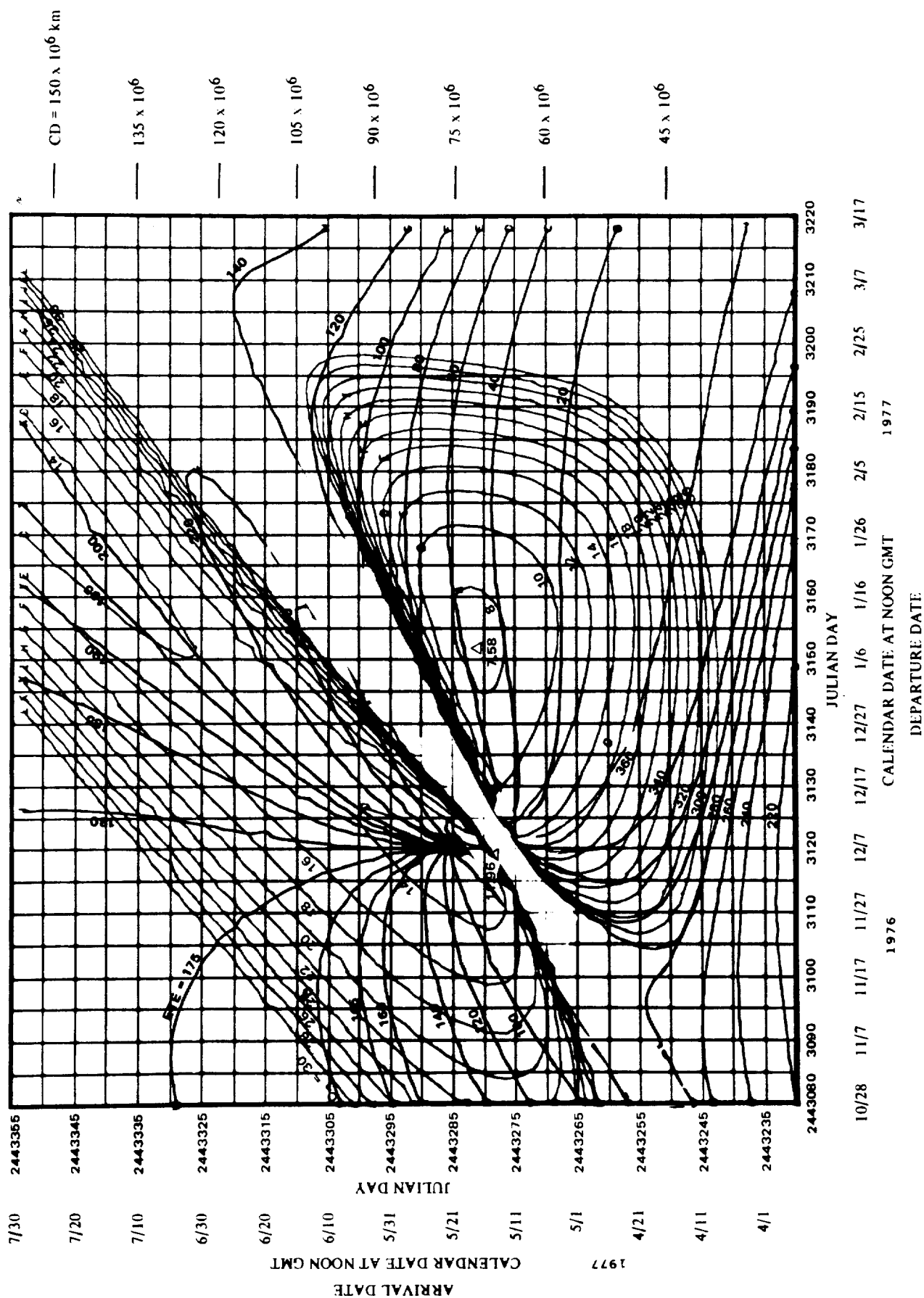


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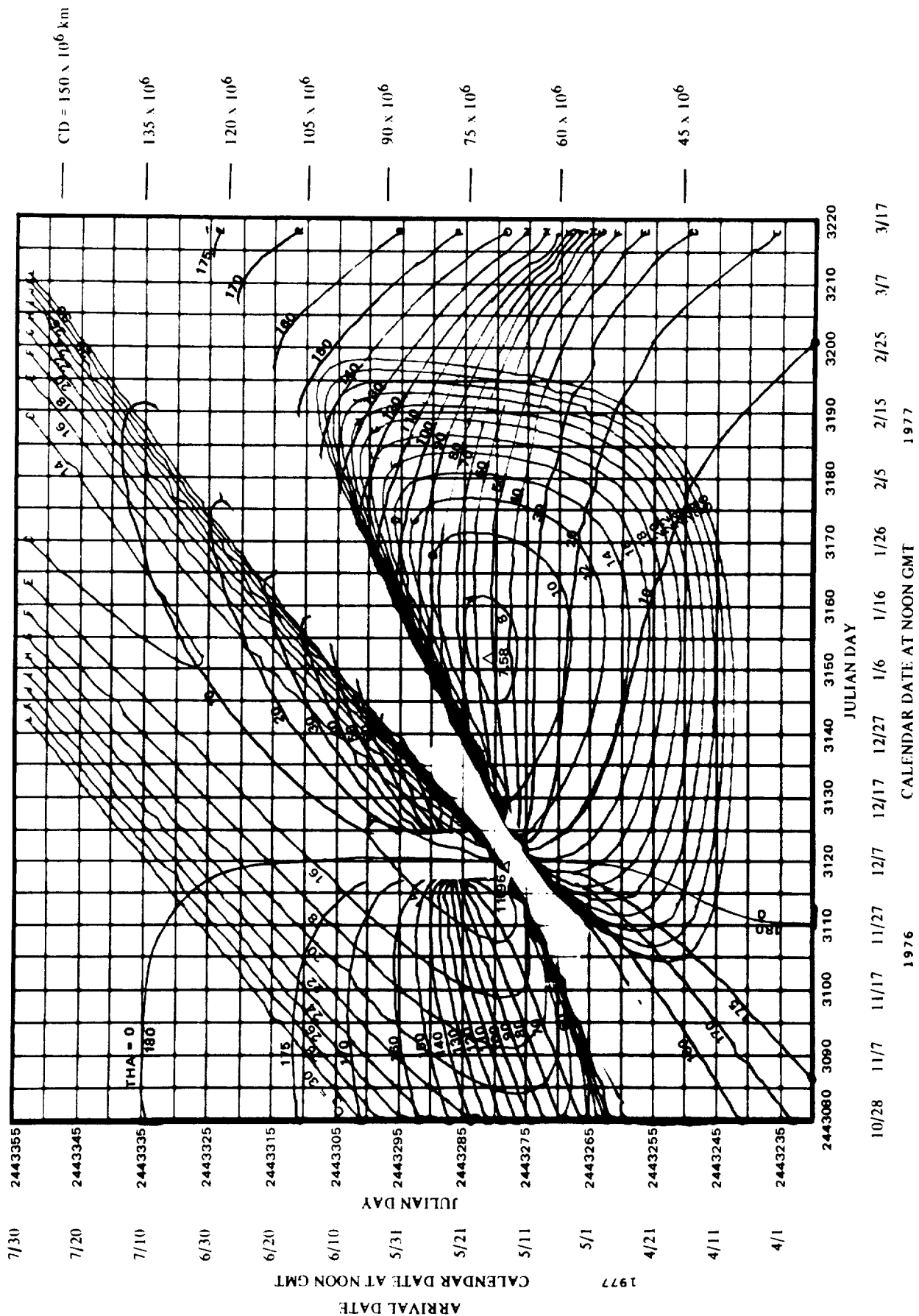


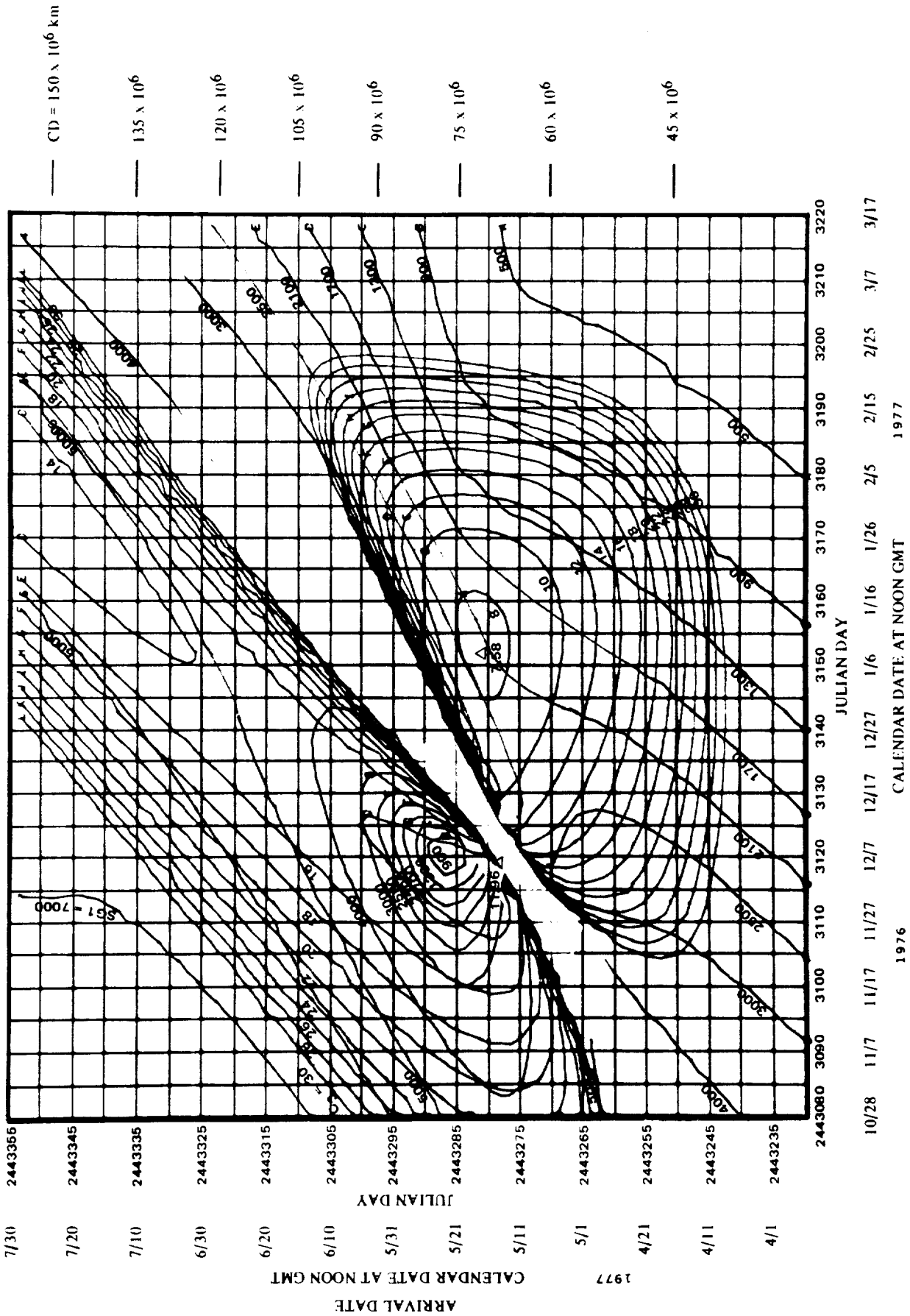
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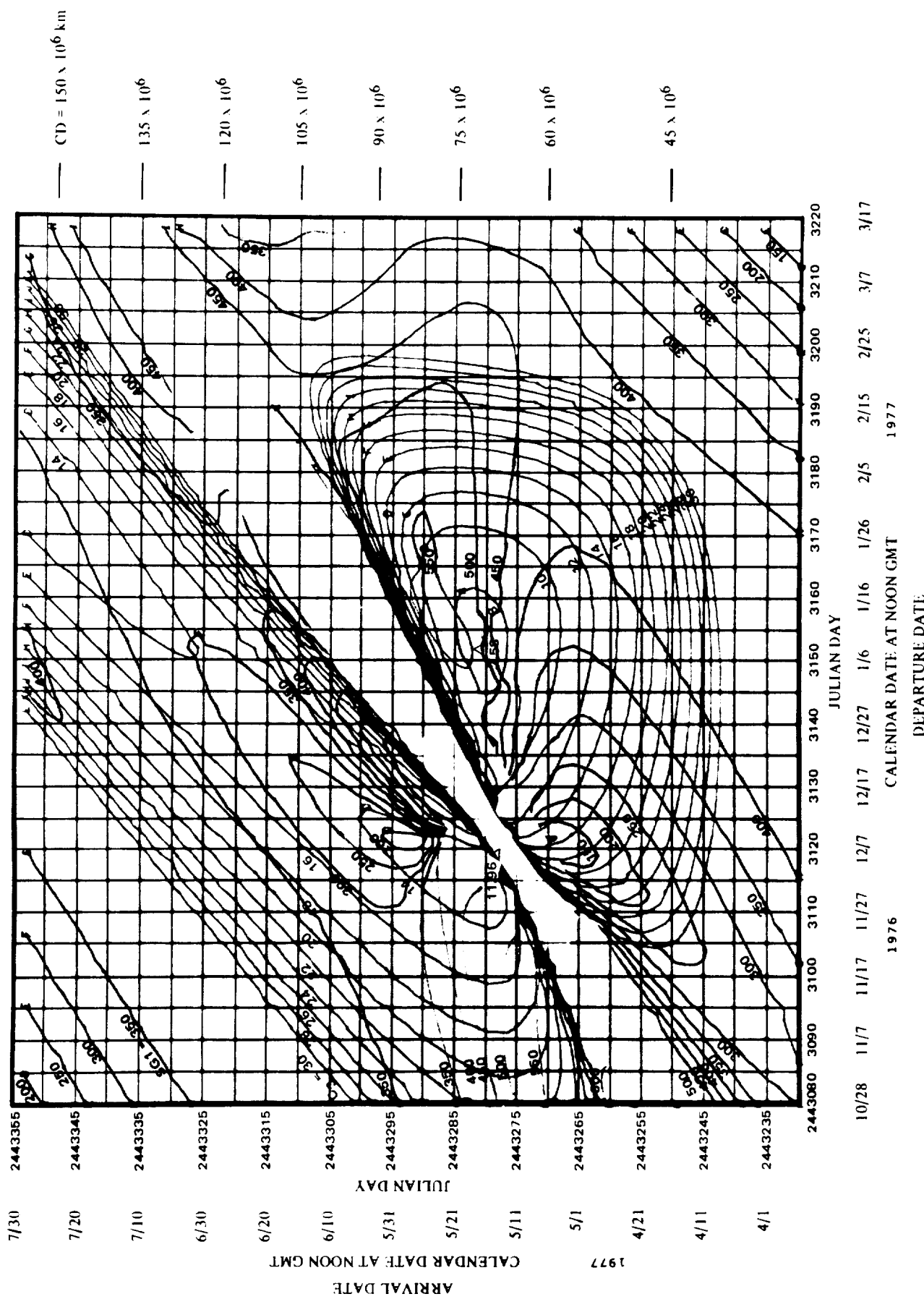


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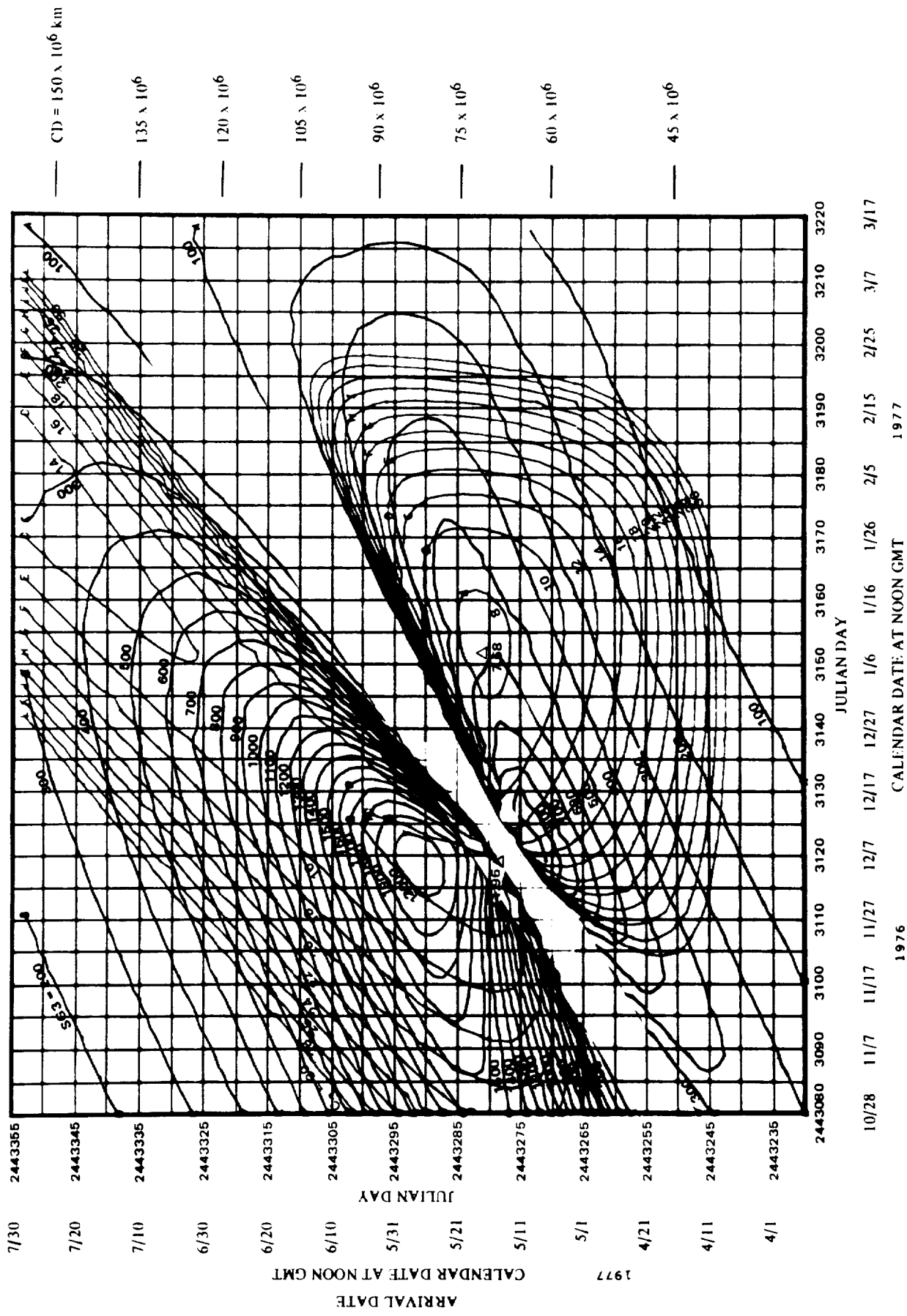




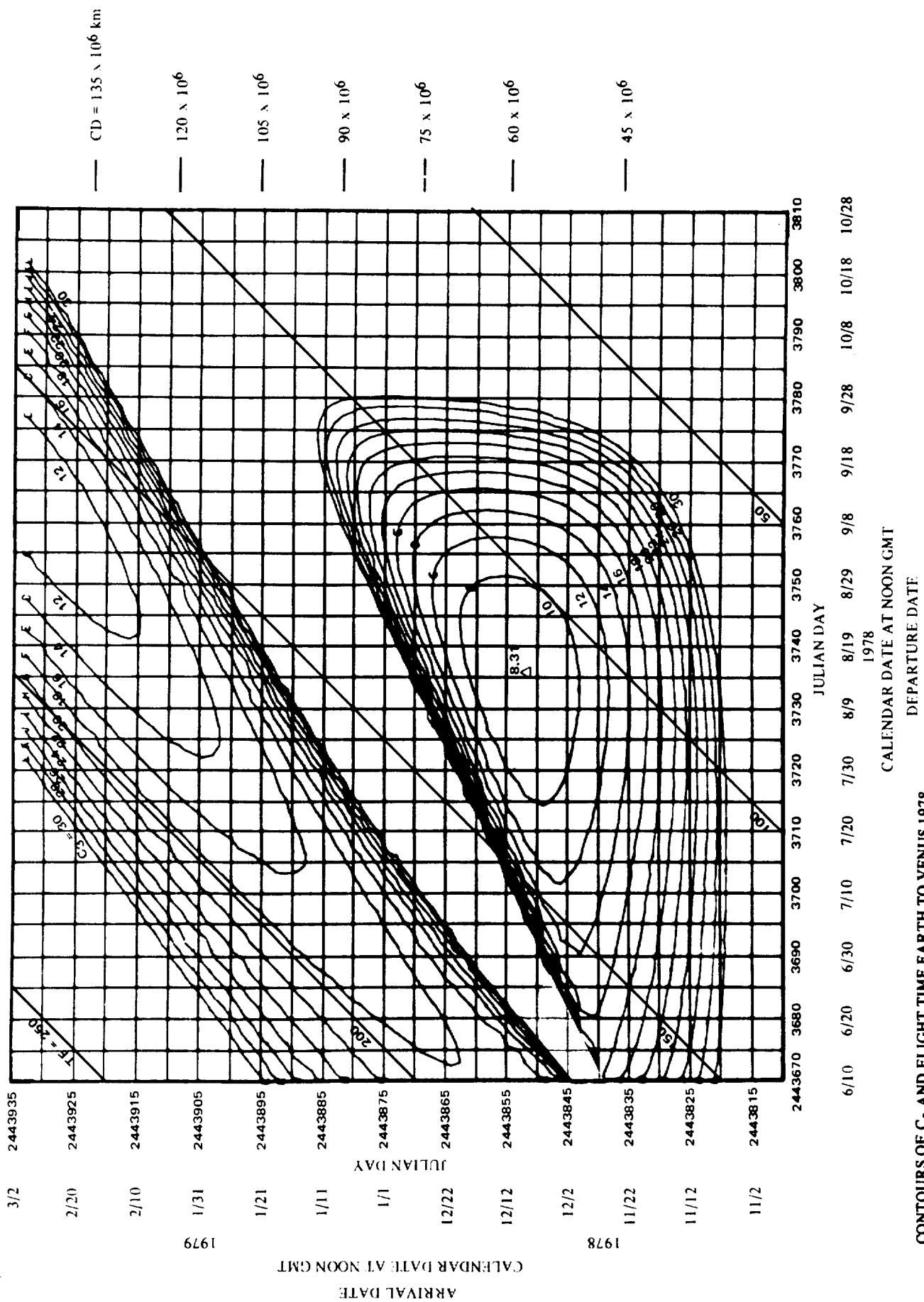
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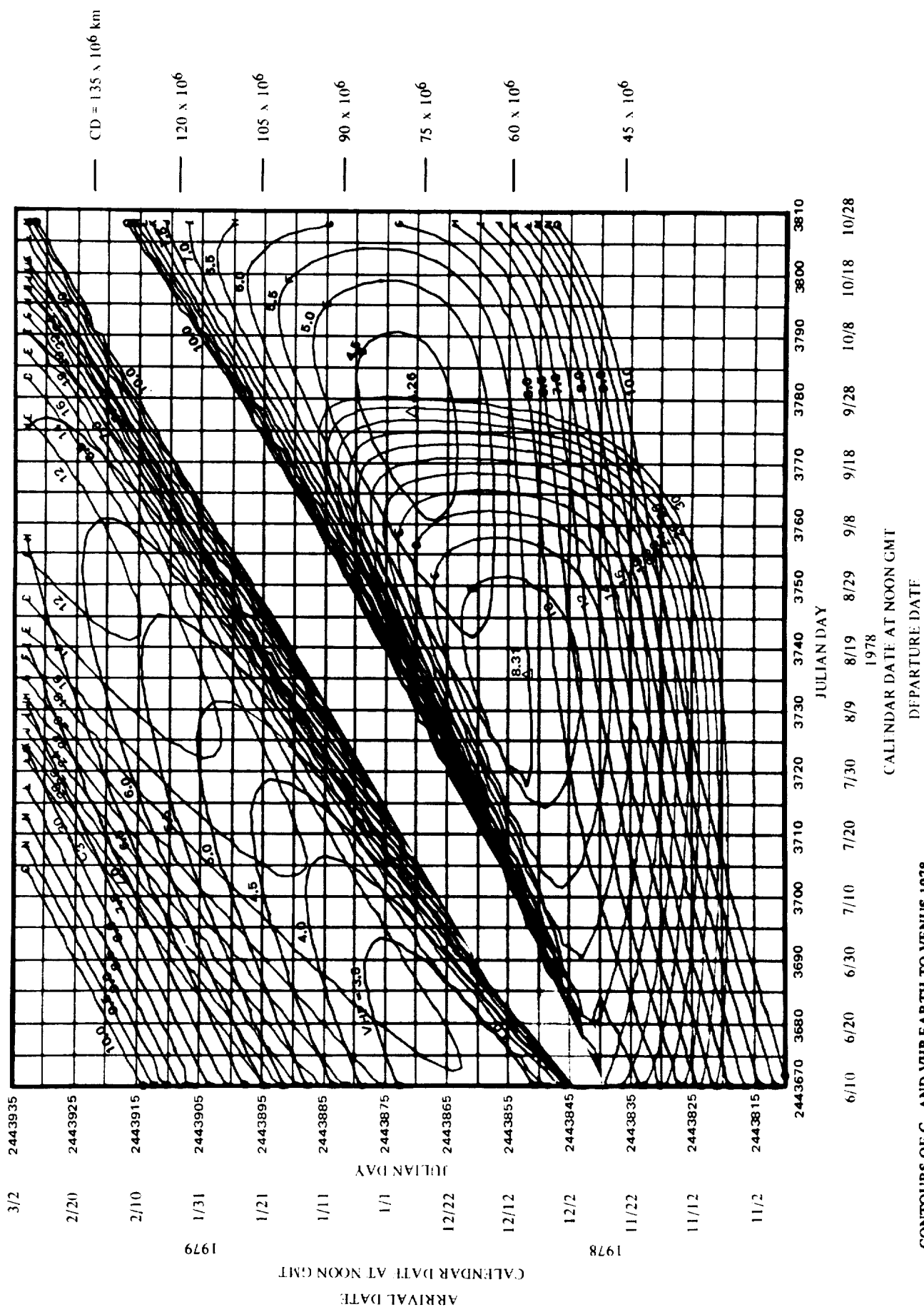


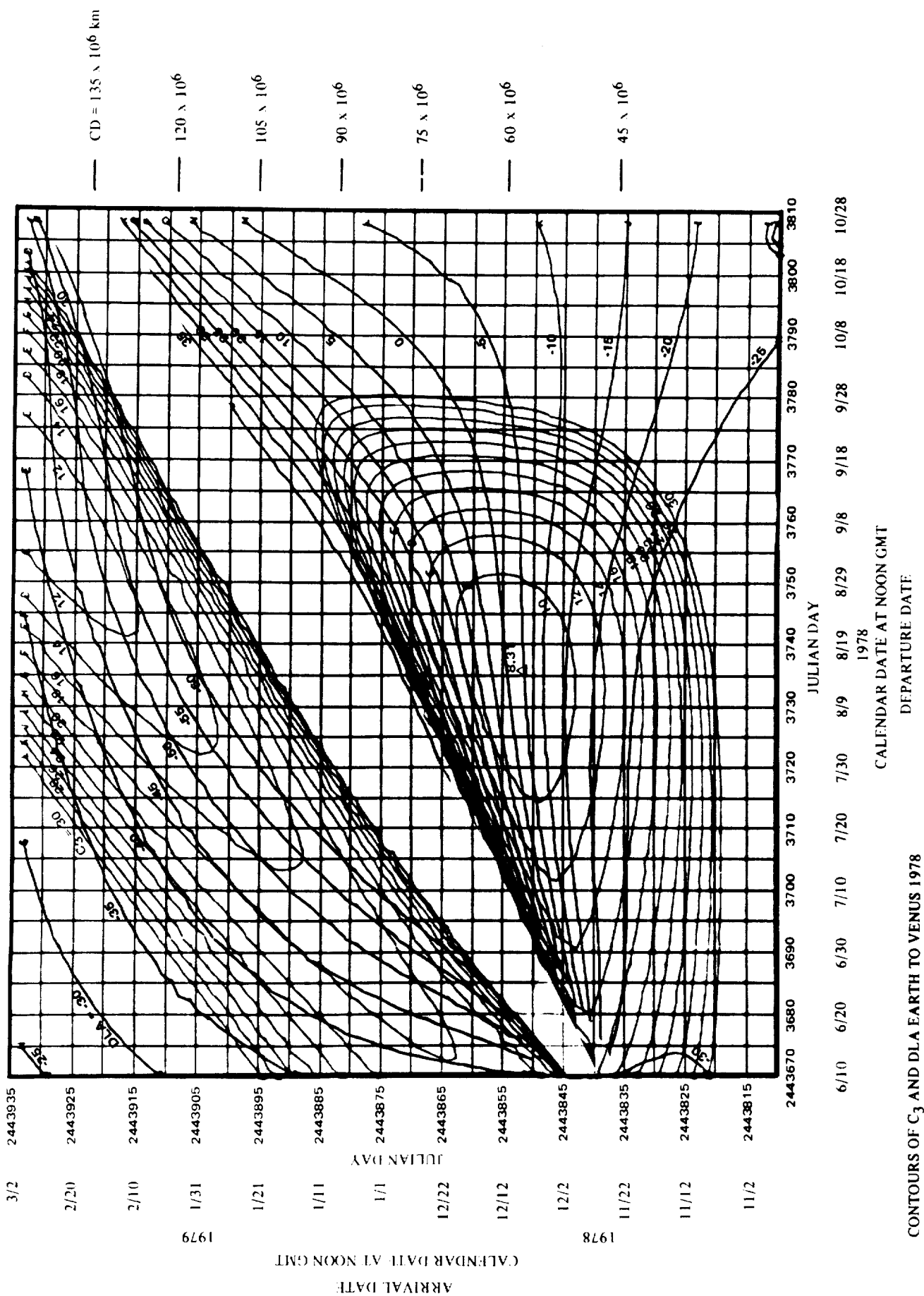
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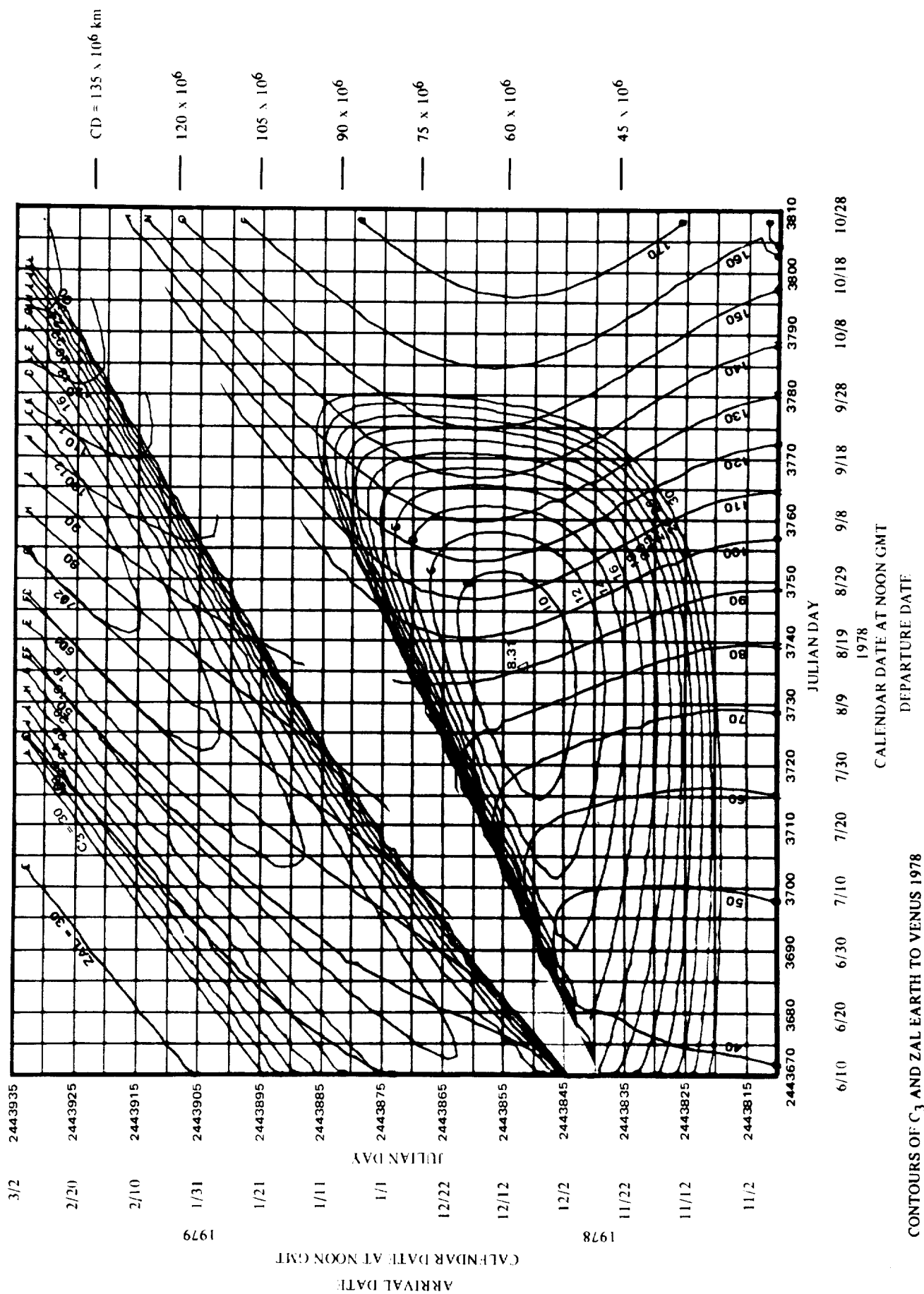


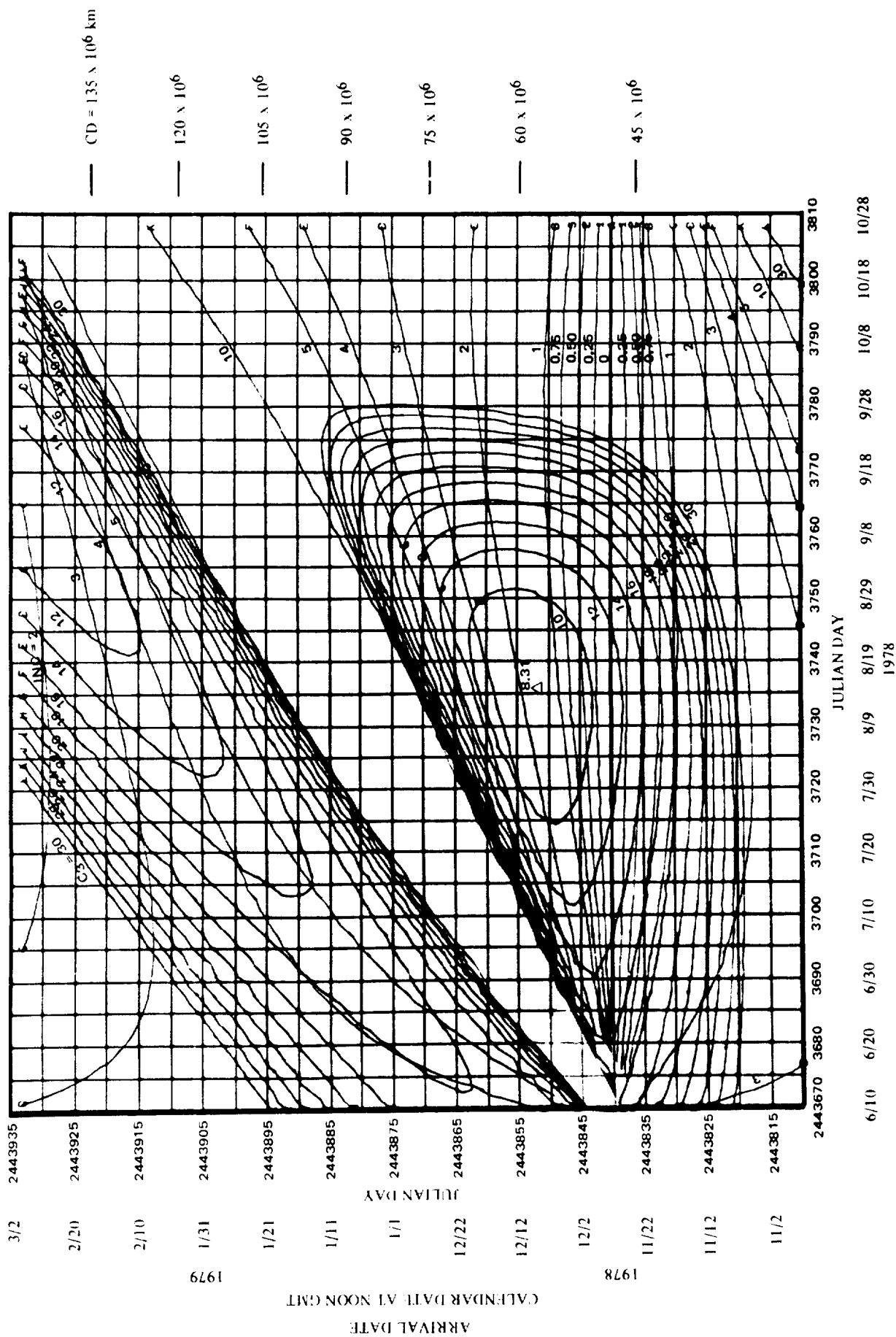
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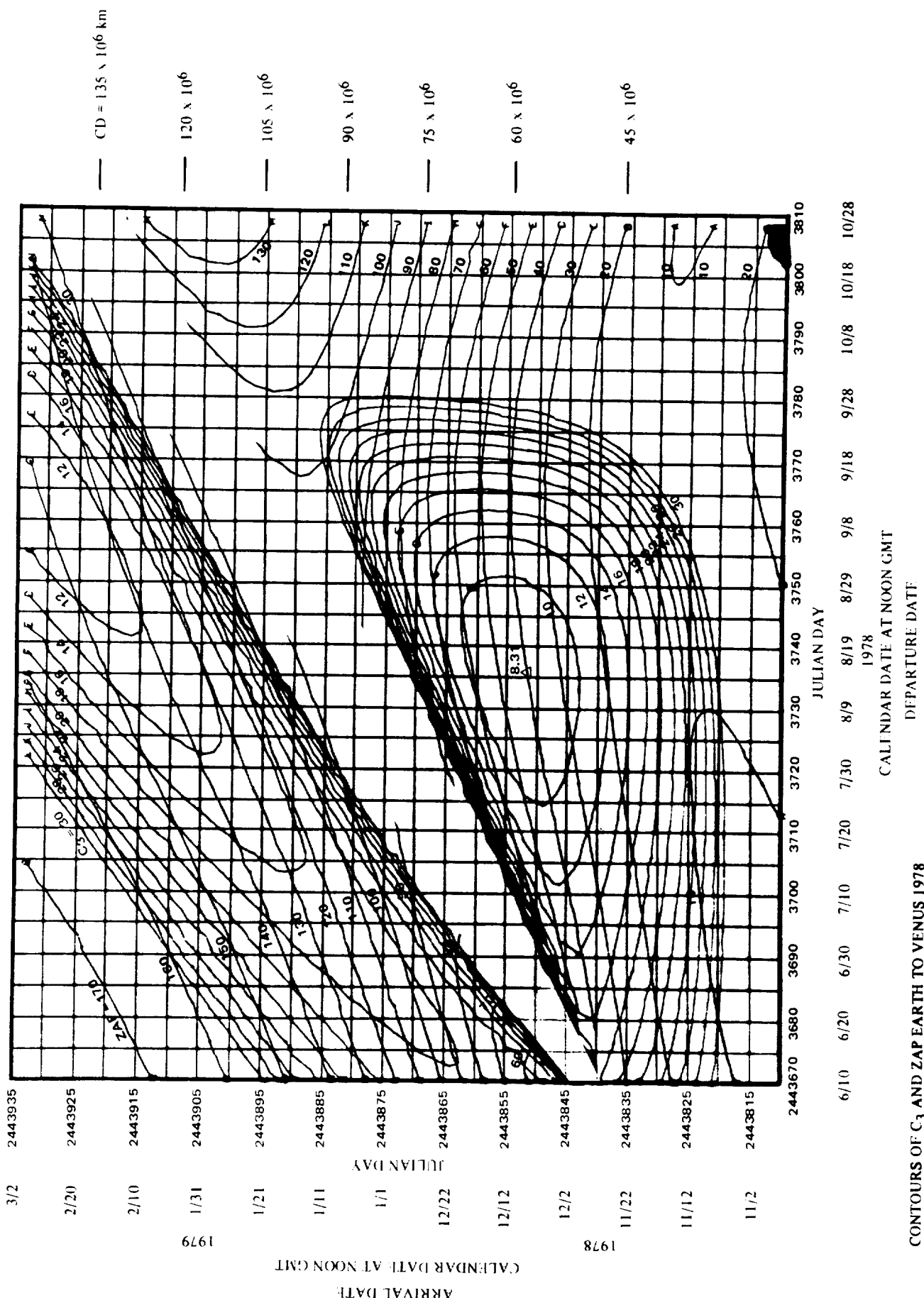


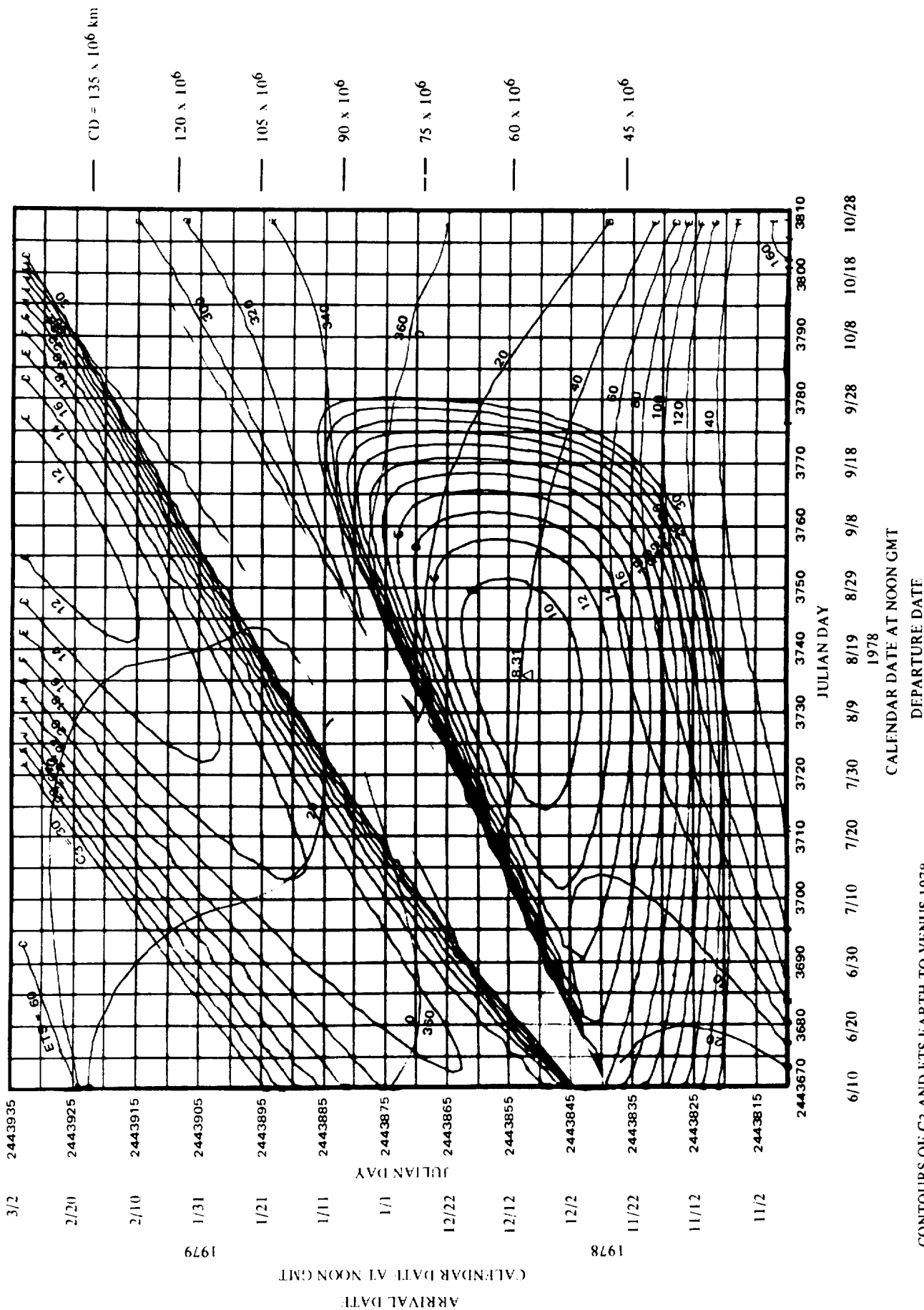


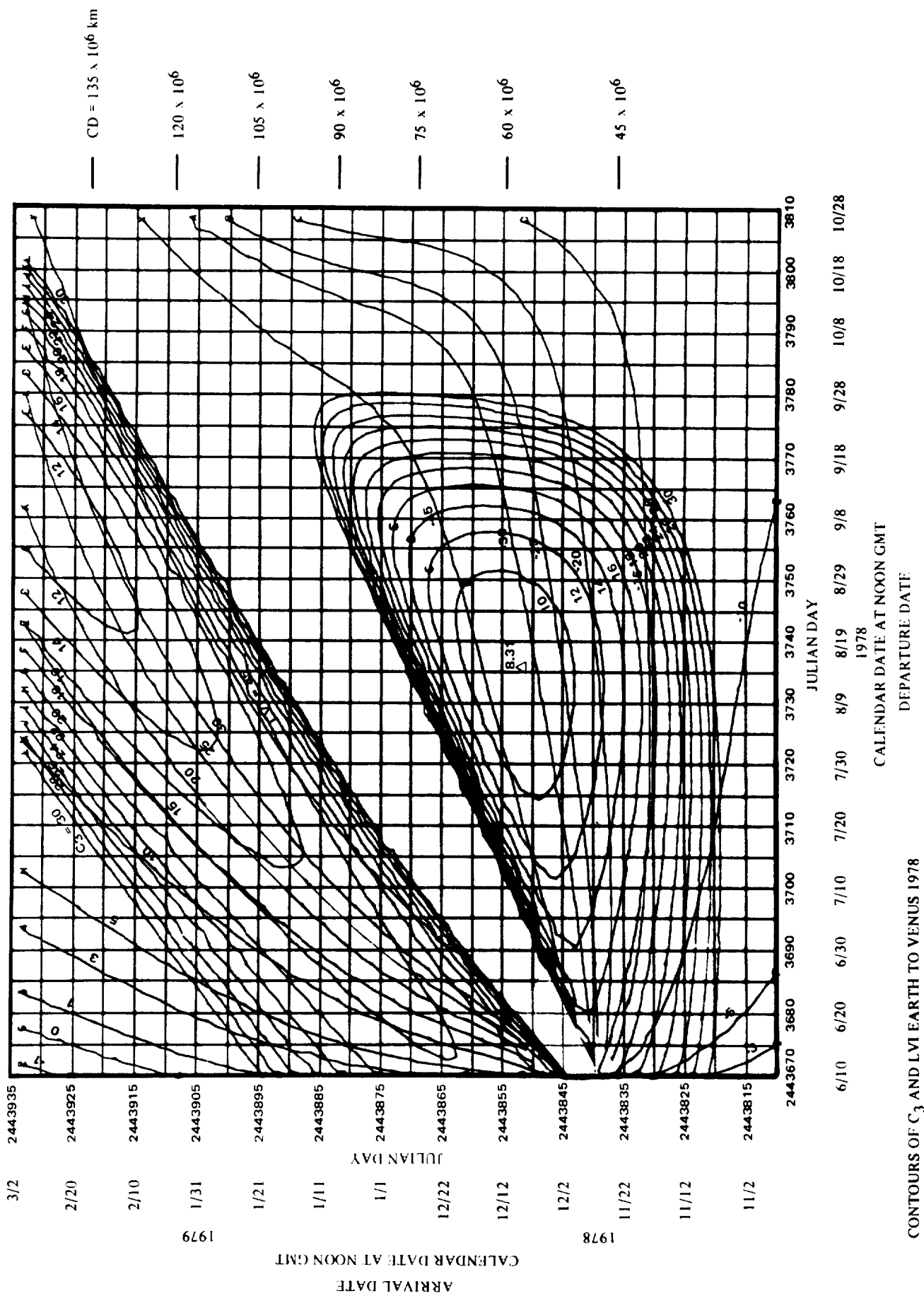


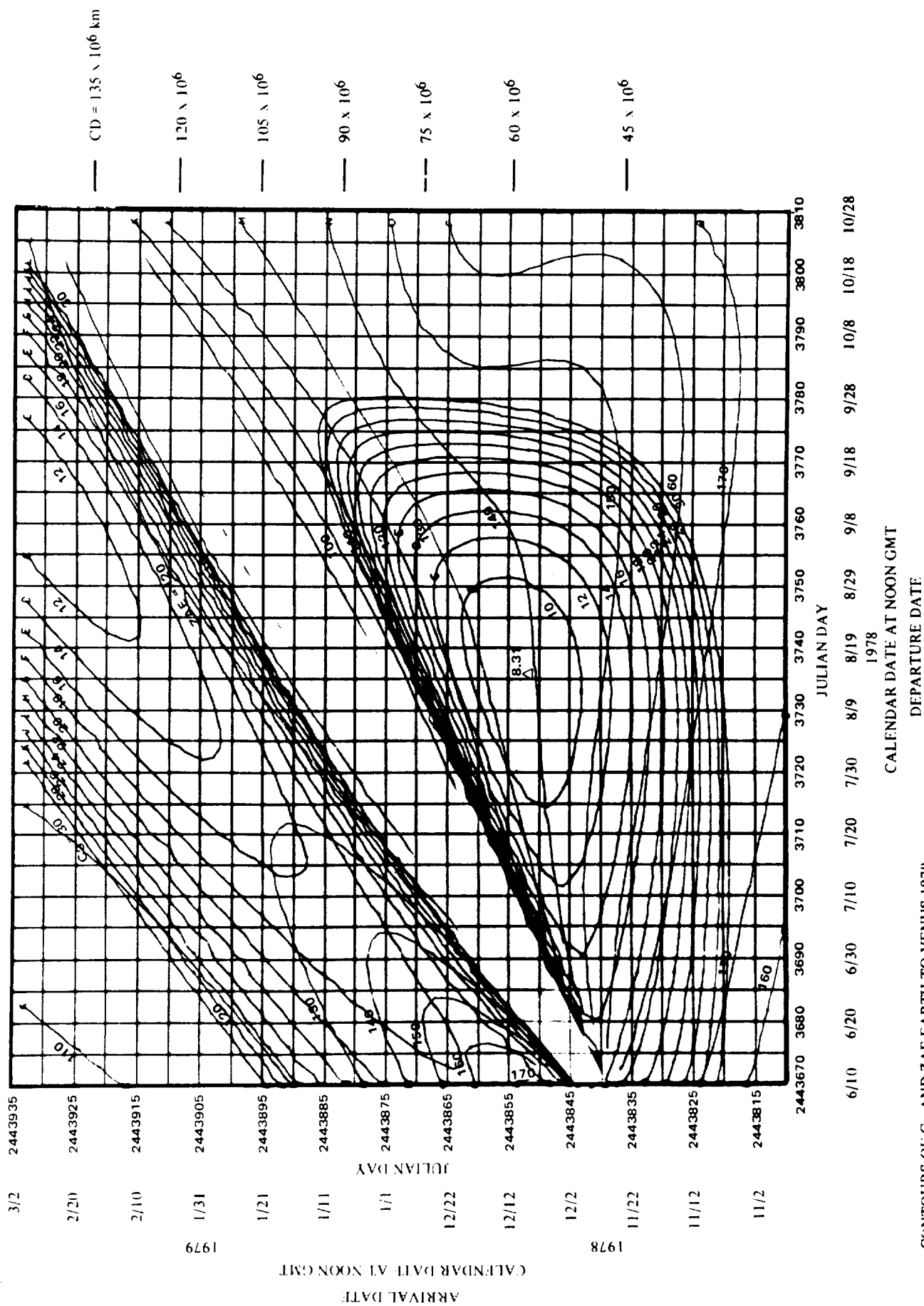


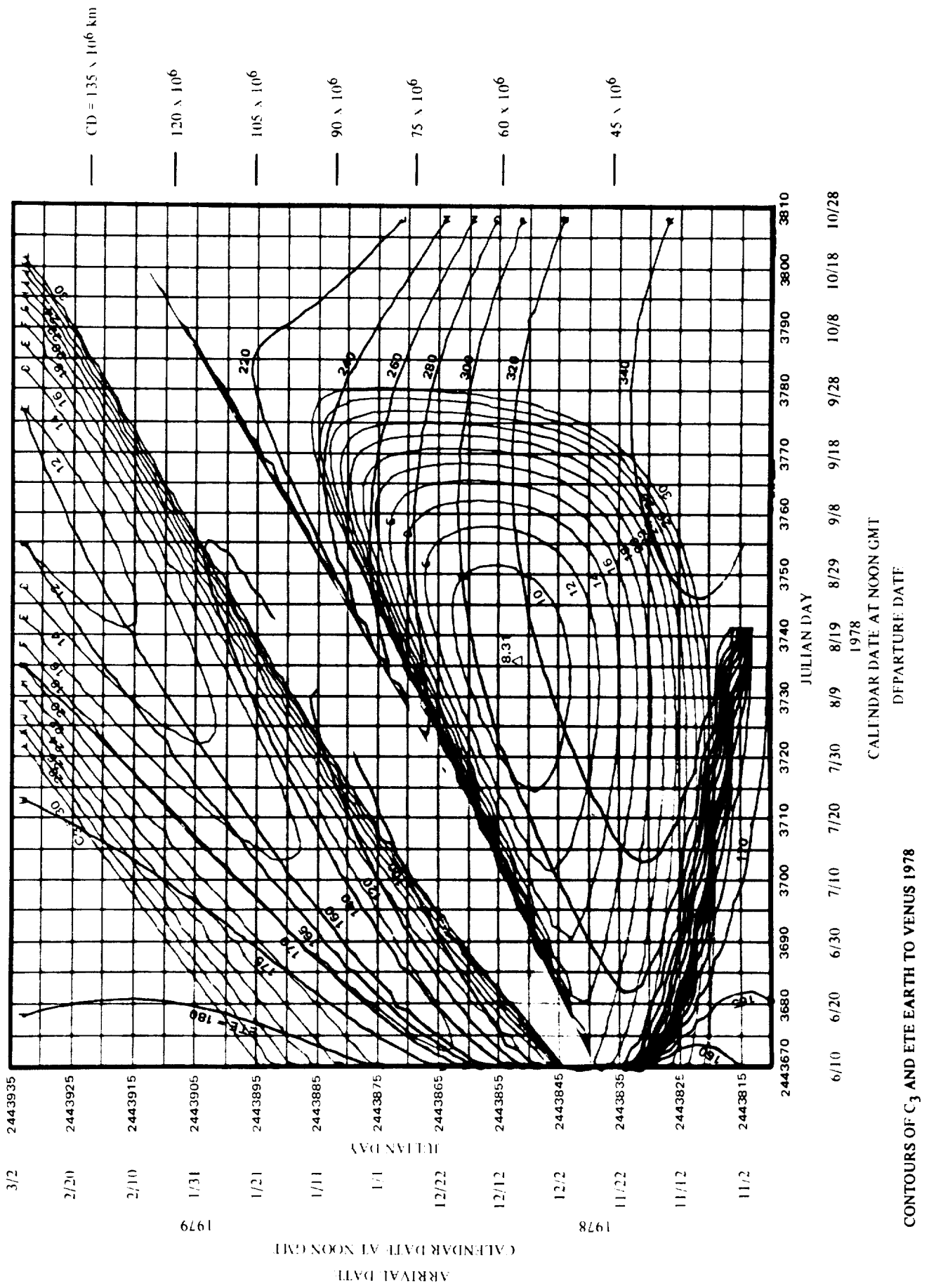
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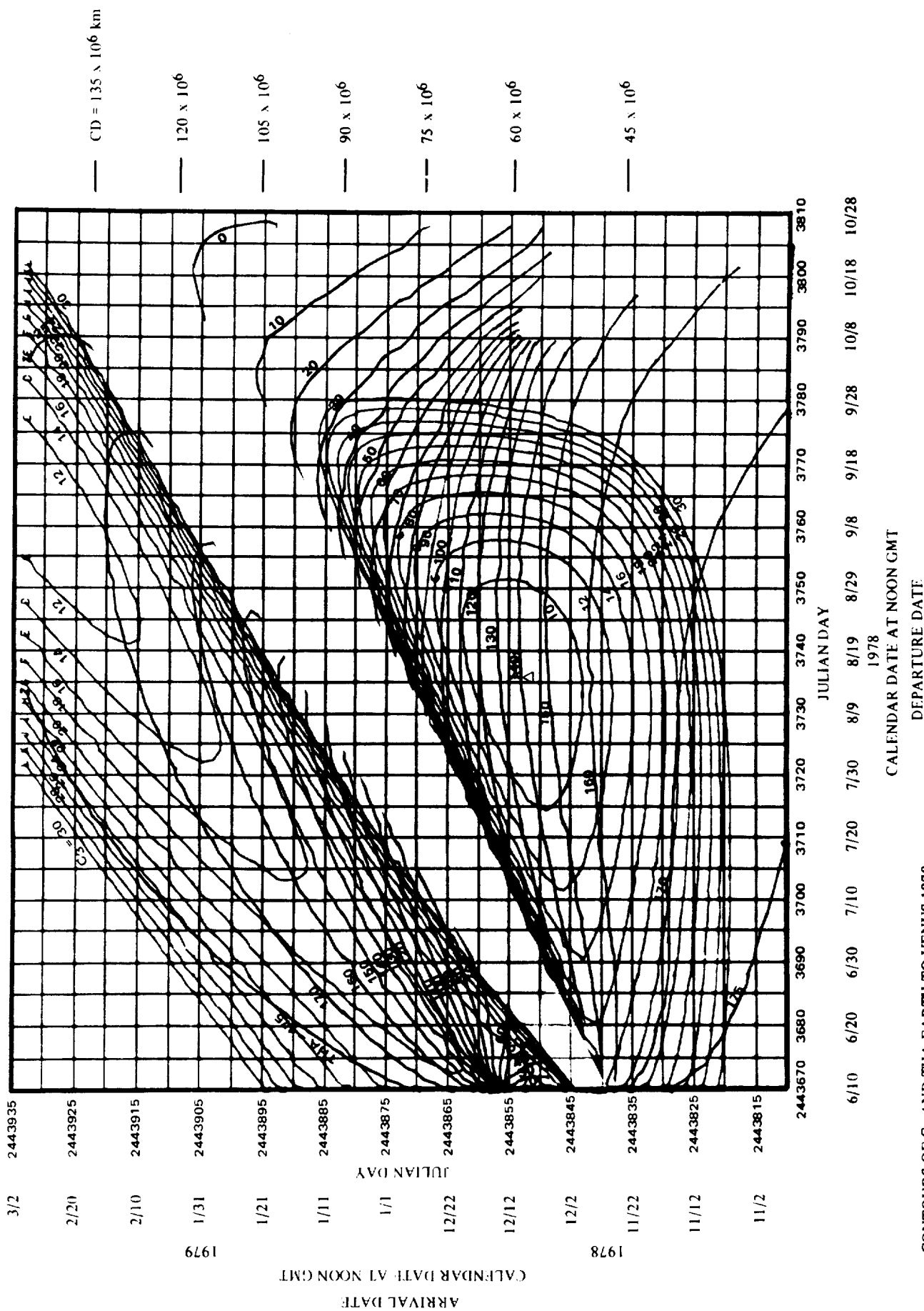


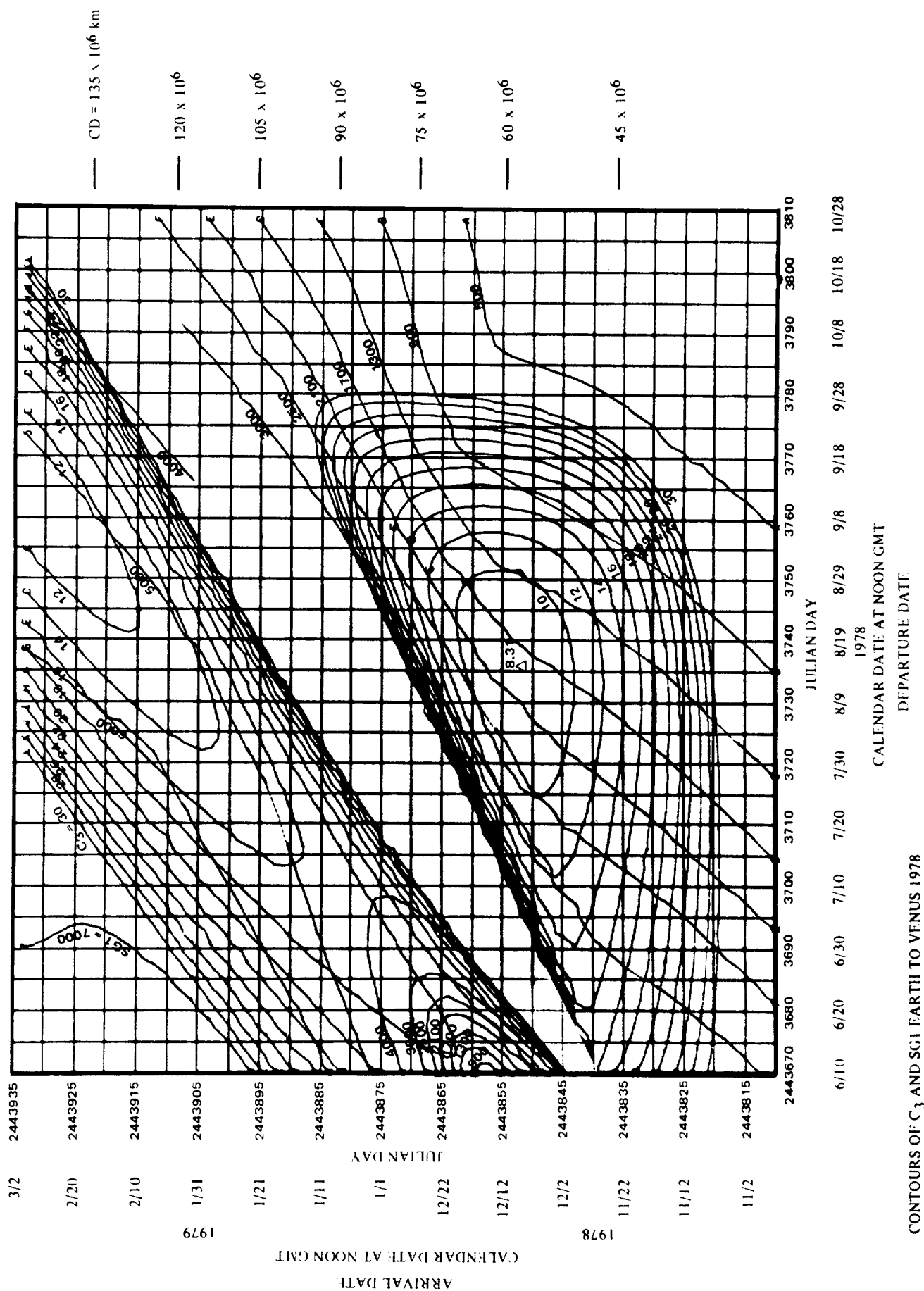


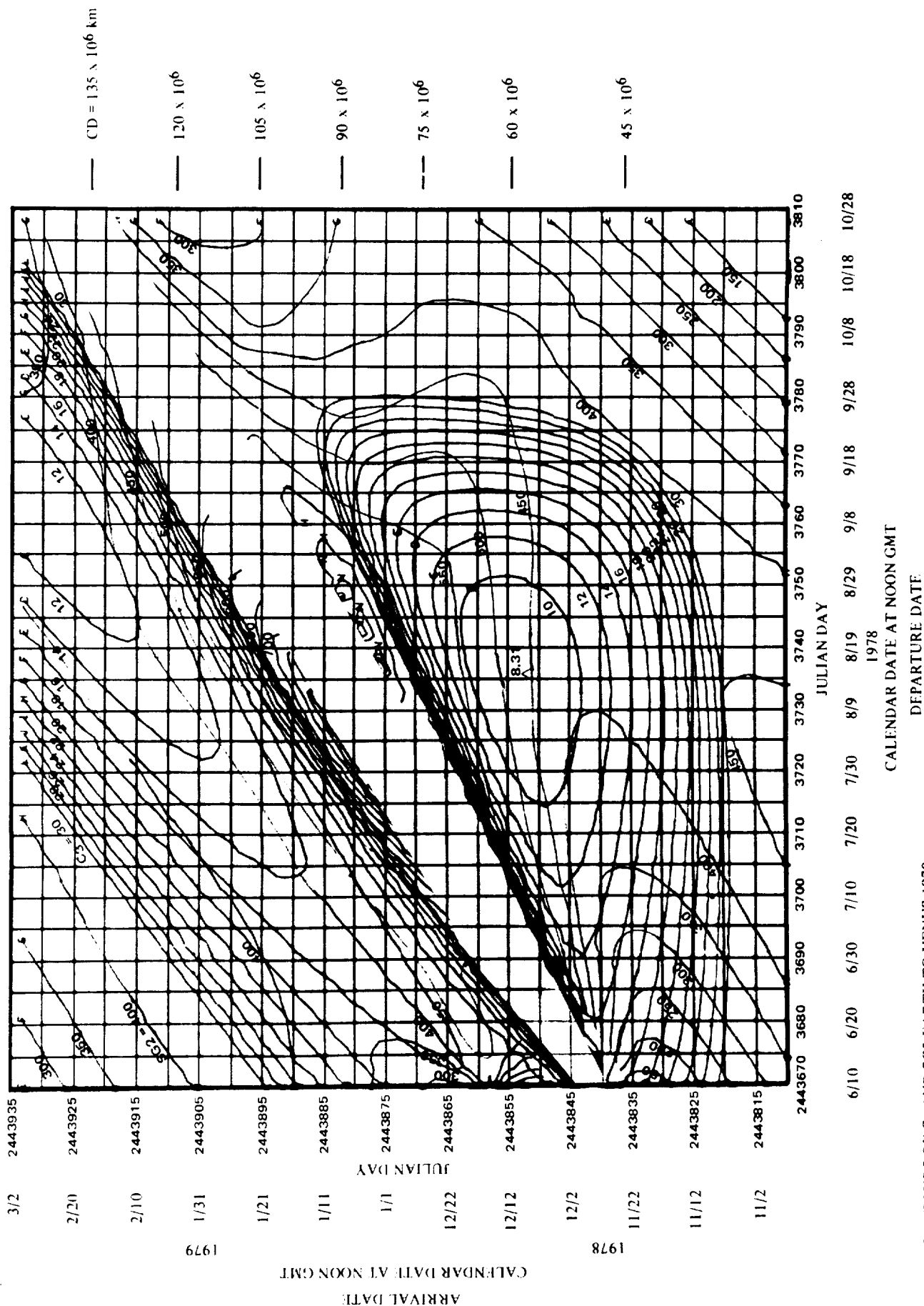




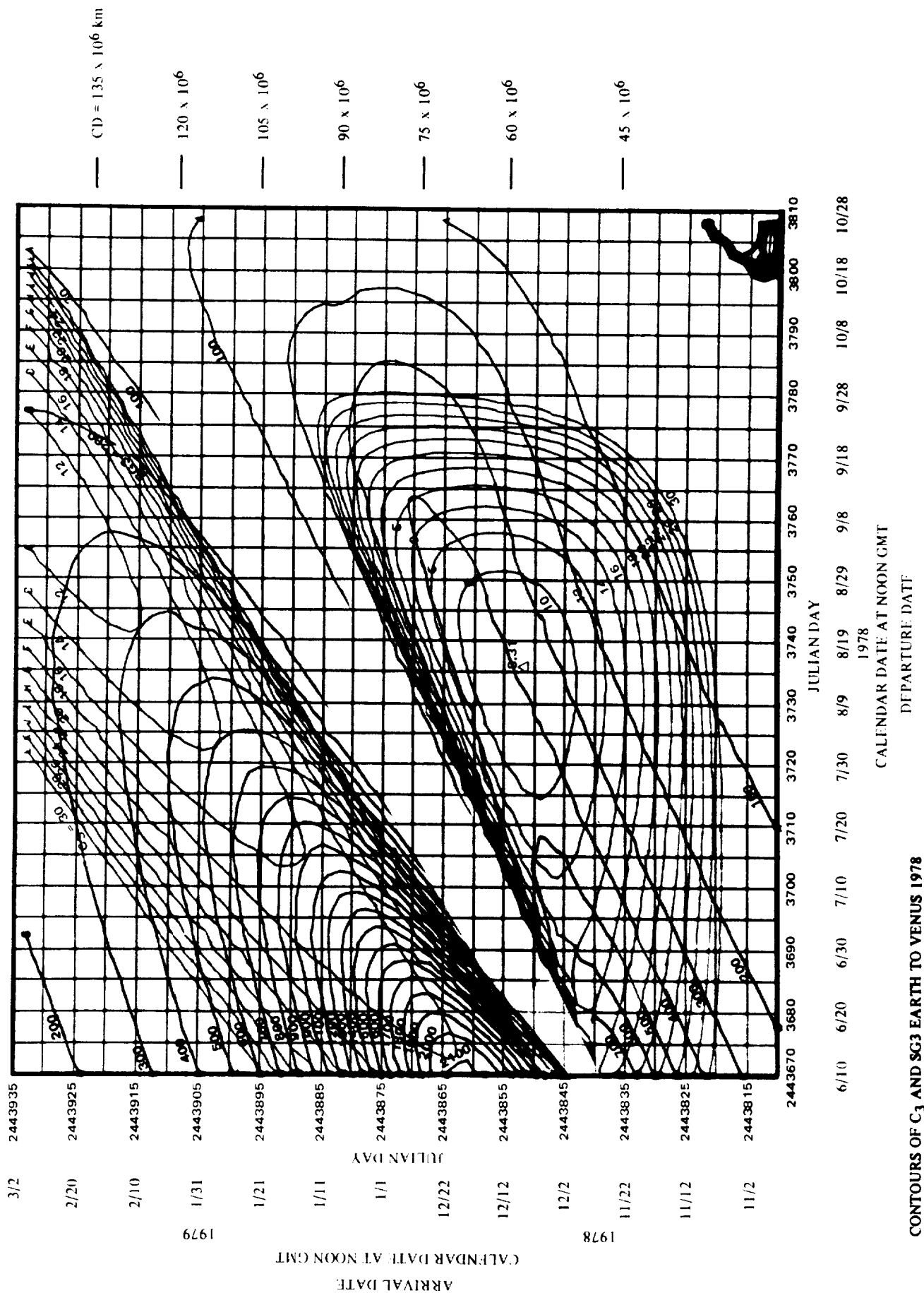


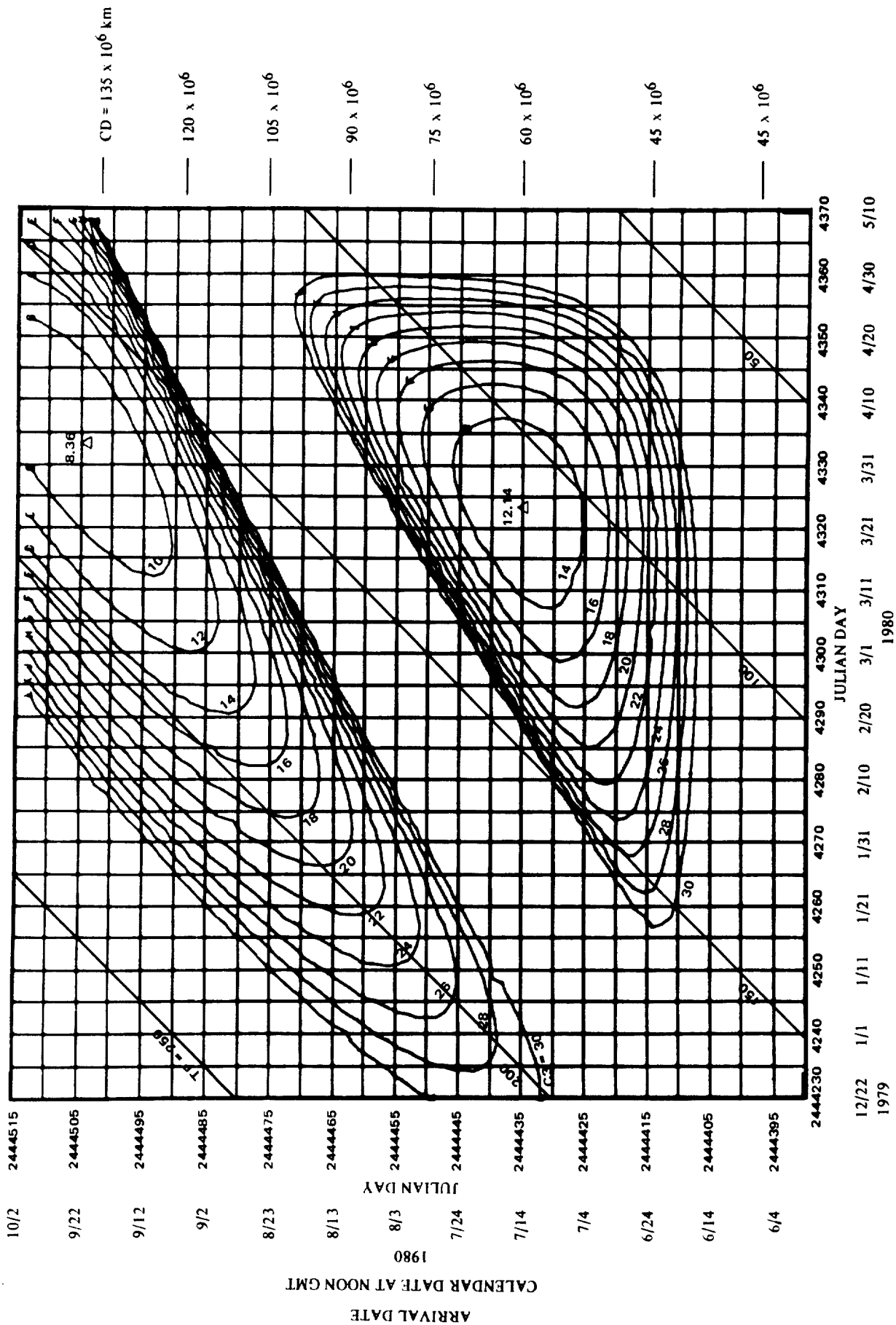


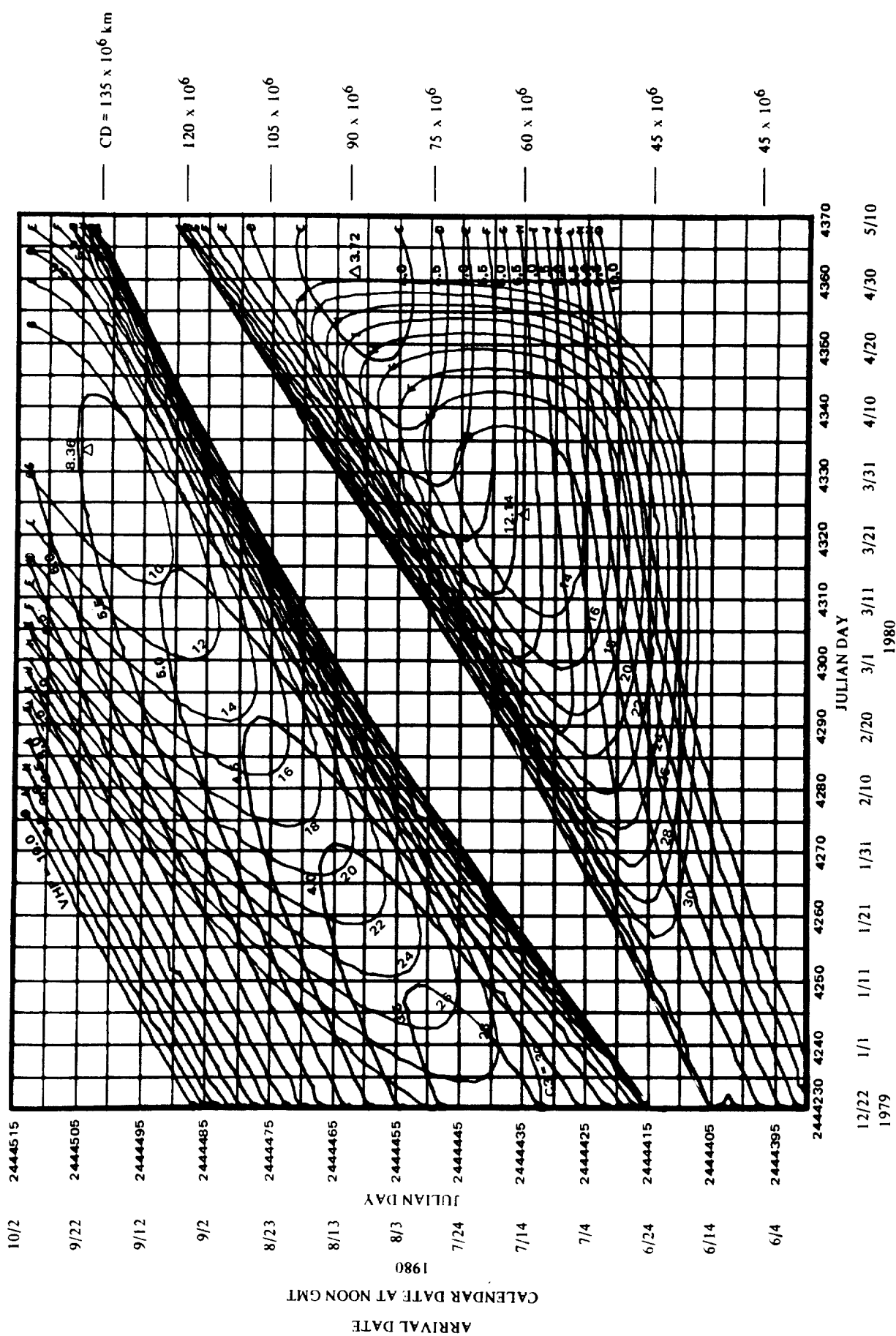




CONTOURS OF C₃ AND SG2 EARTH TO VENUS 1978





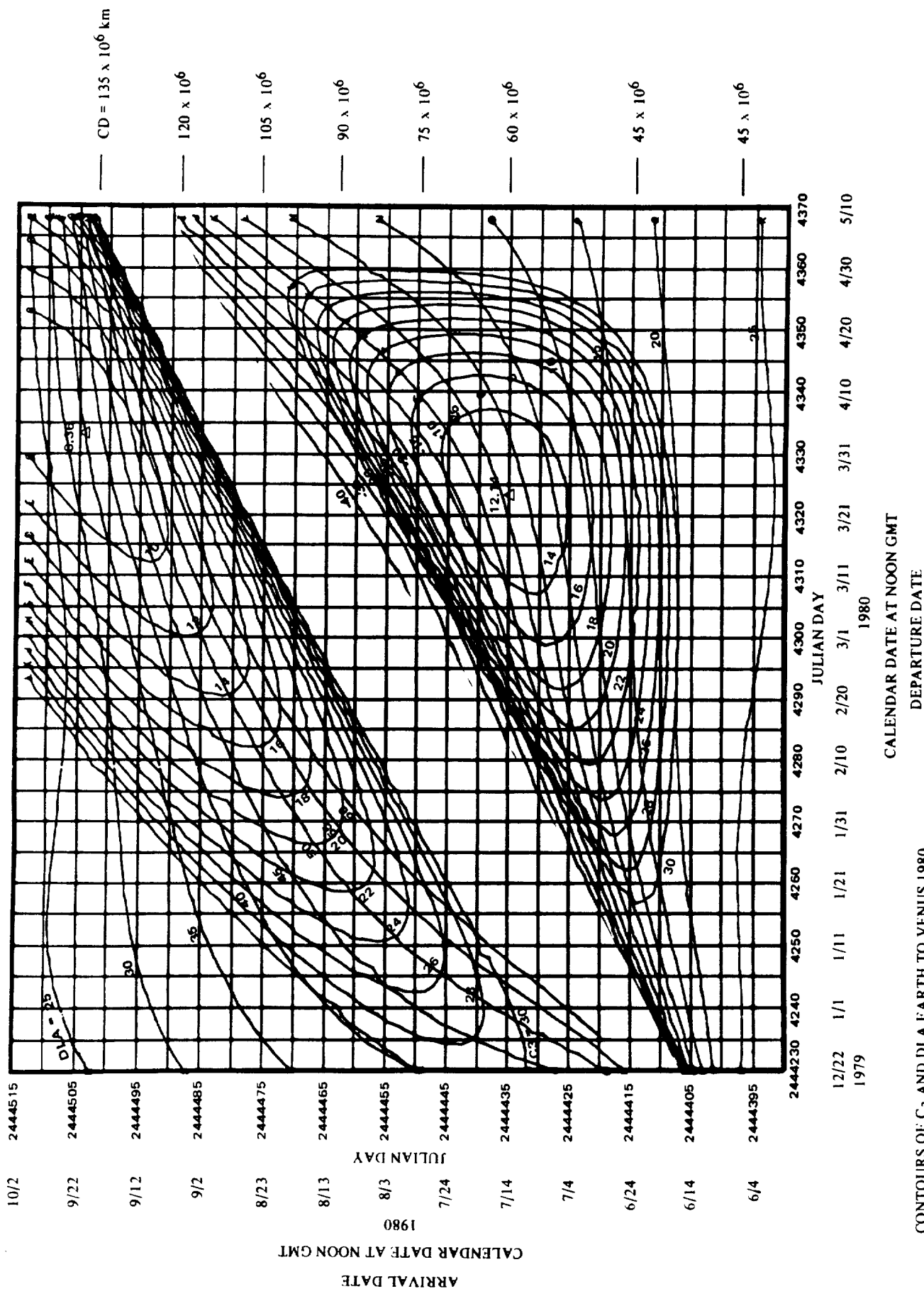


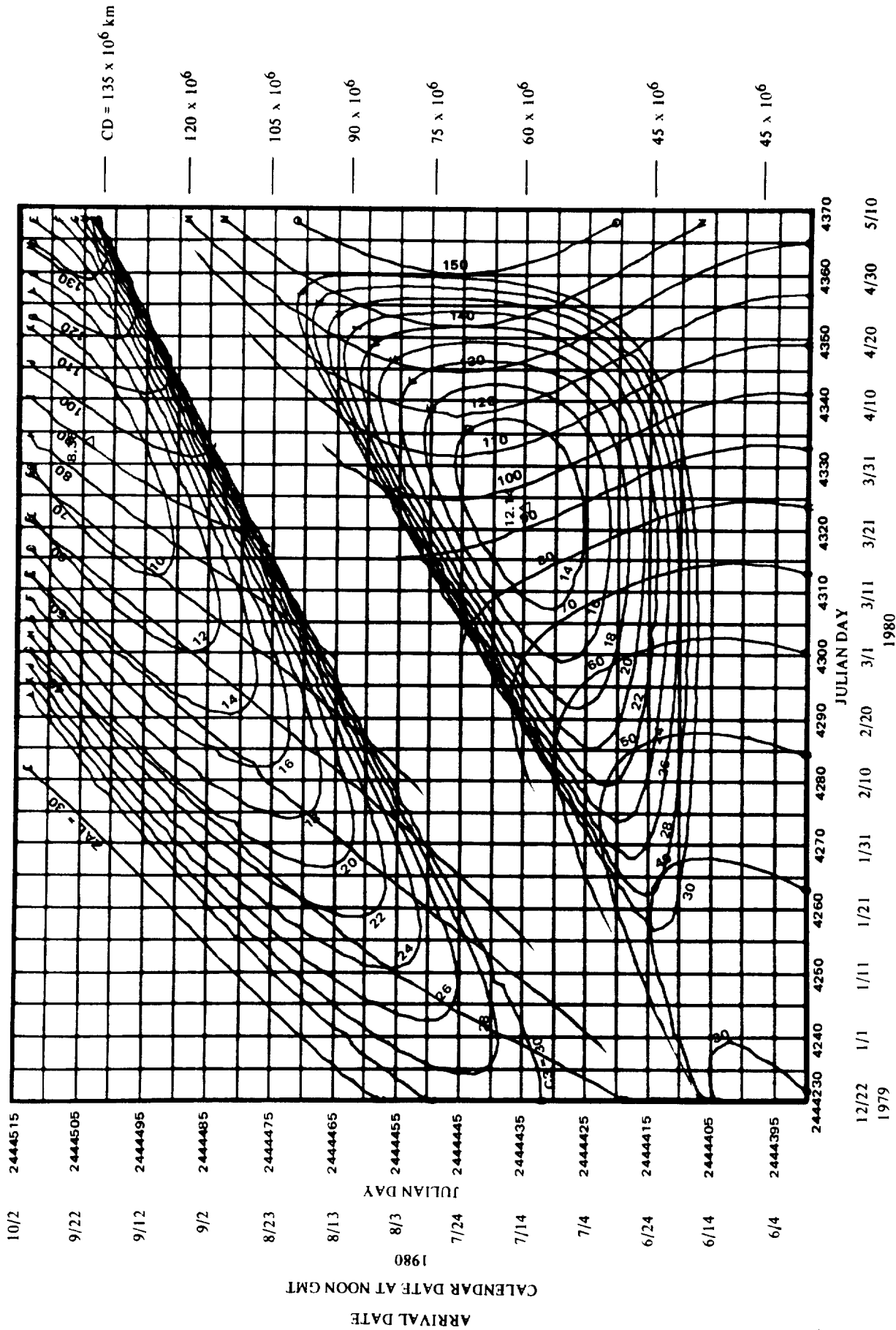
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CALENDAR DATE AT NOON GMT

DEPARTURE DATE

1980

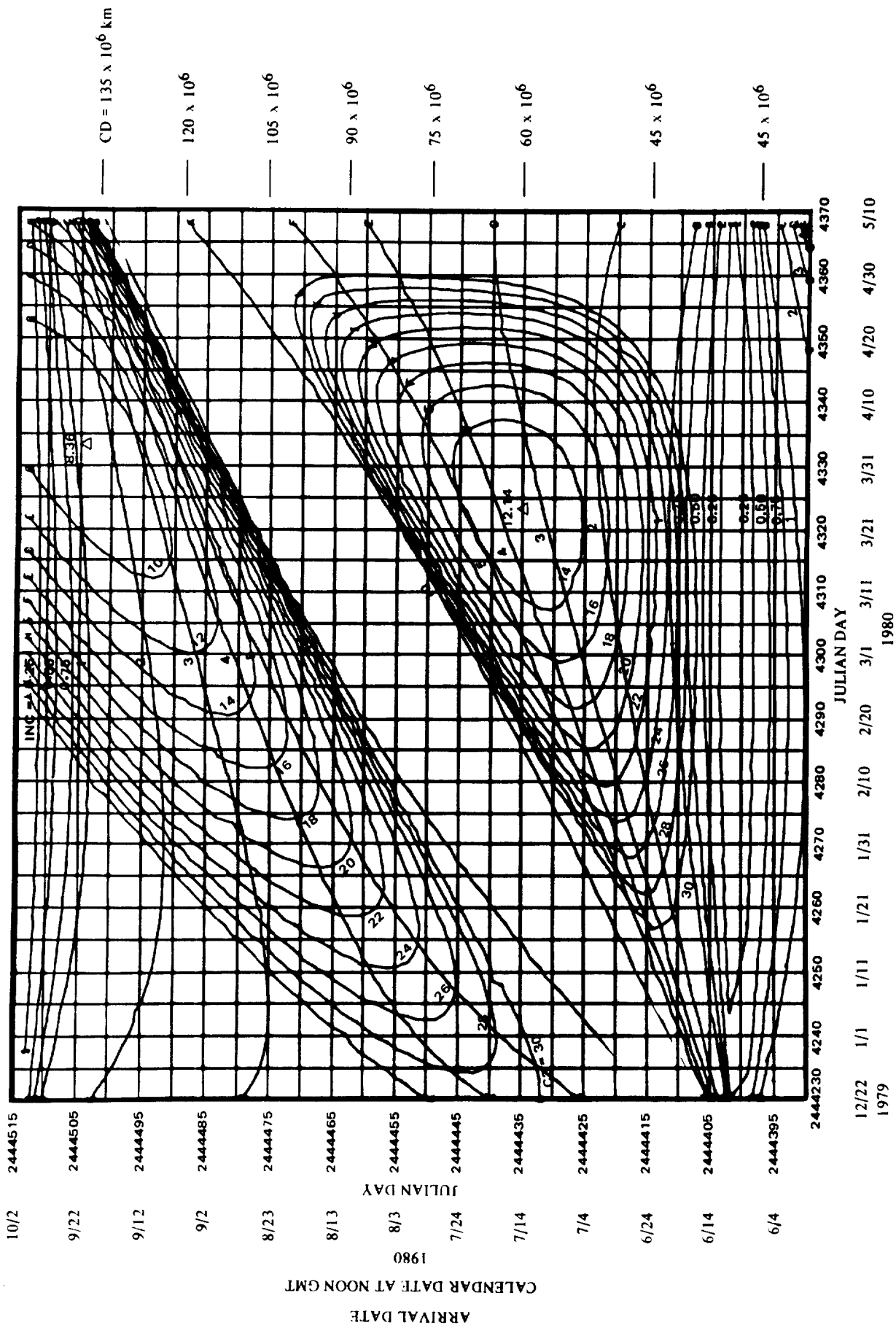




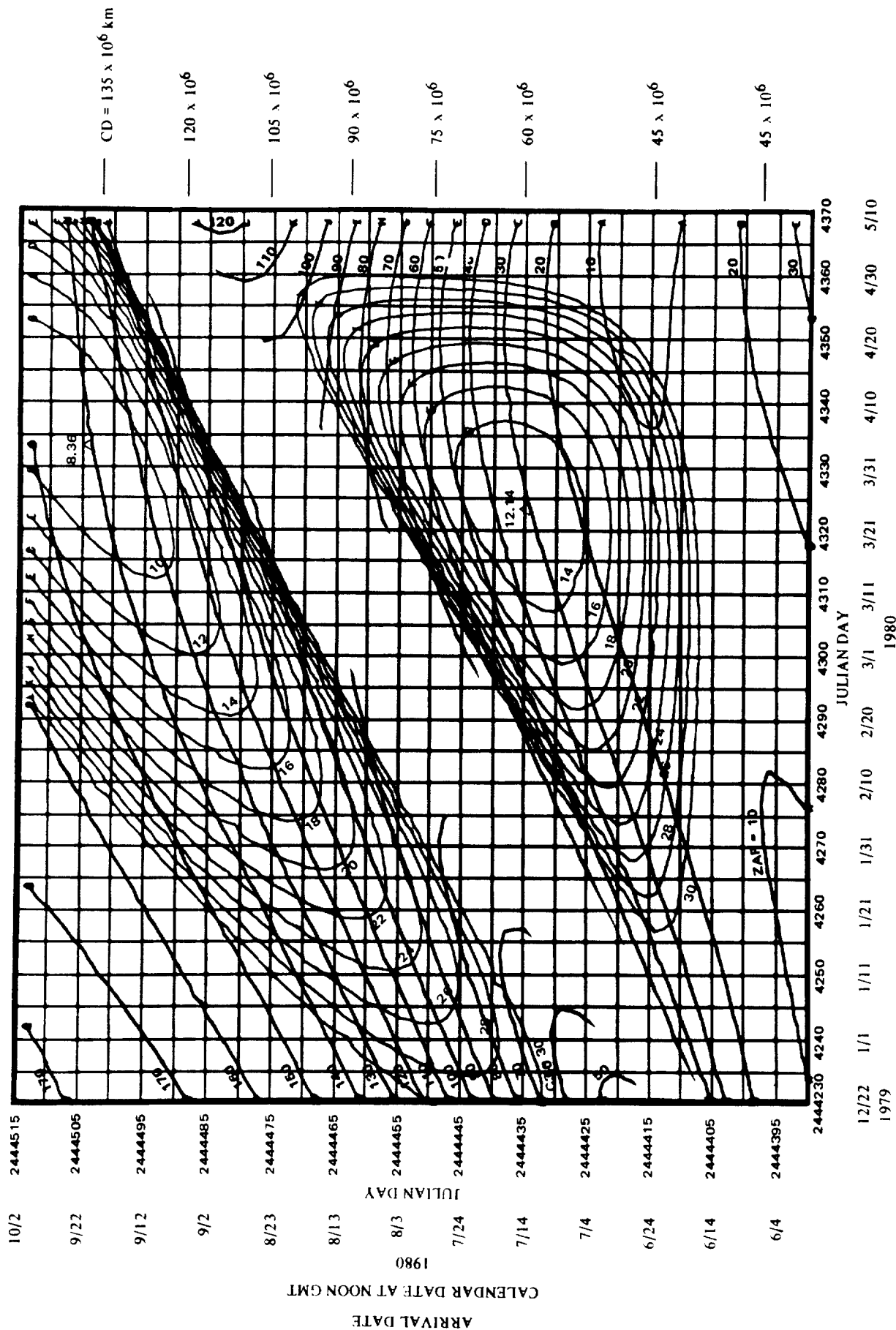
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CALENDAR DATE AT NOON GMT

DEPARTURE DATE



CONTOURS OF C_3 AND INC EARTH TO VENUS 1980



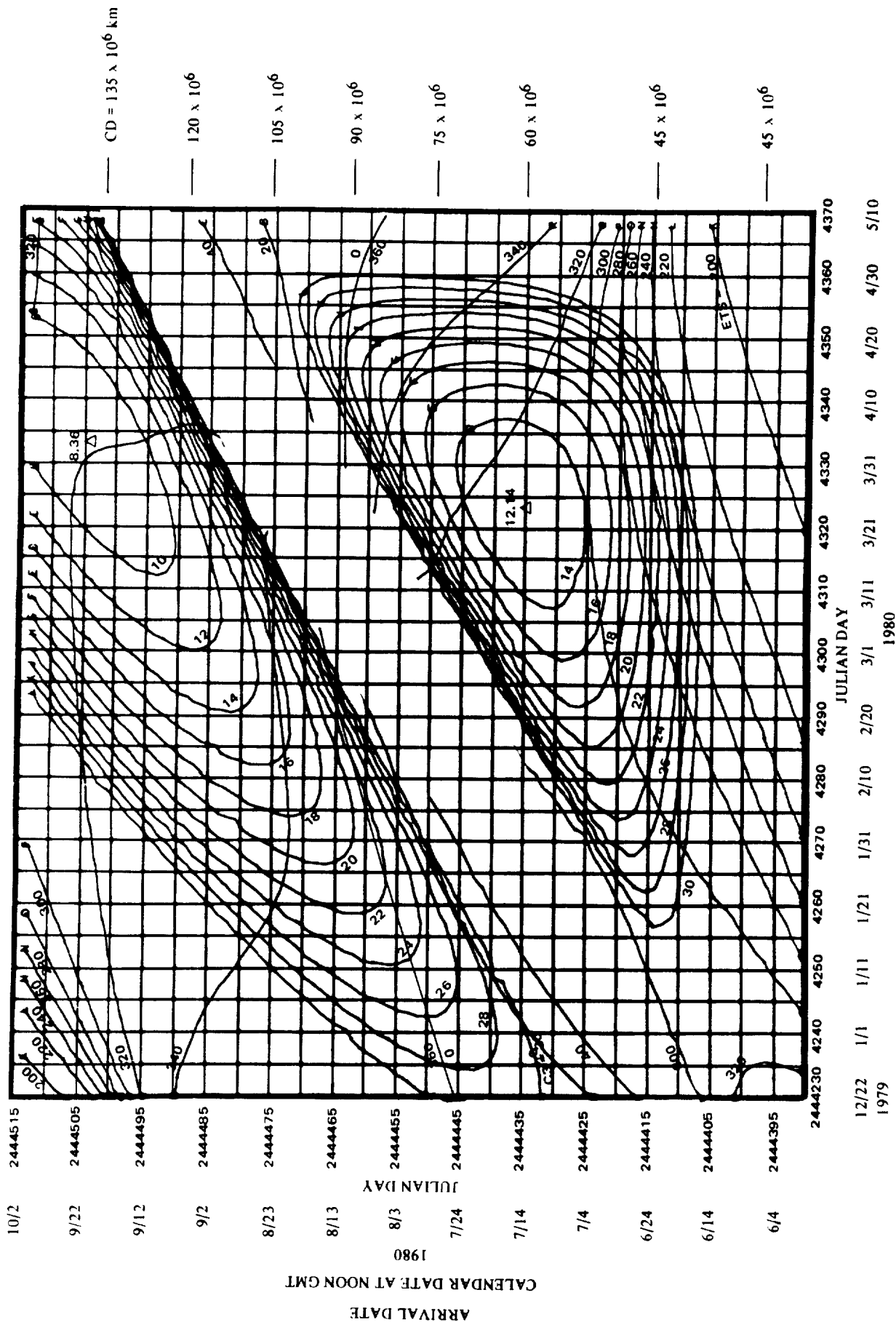
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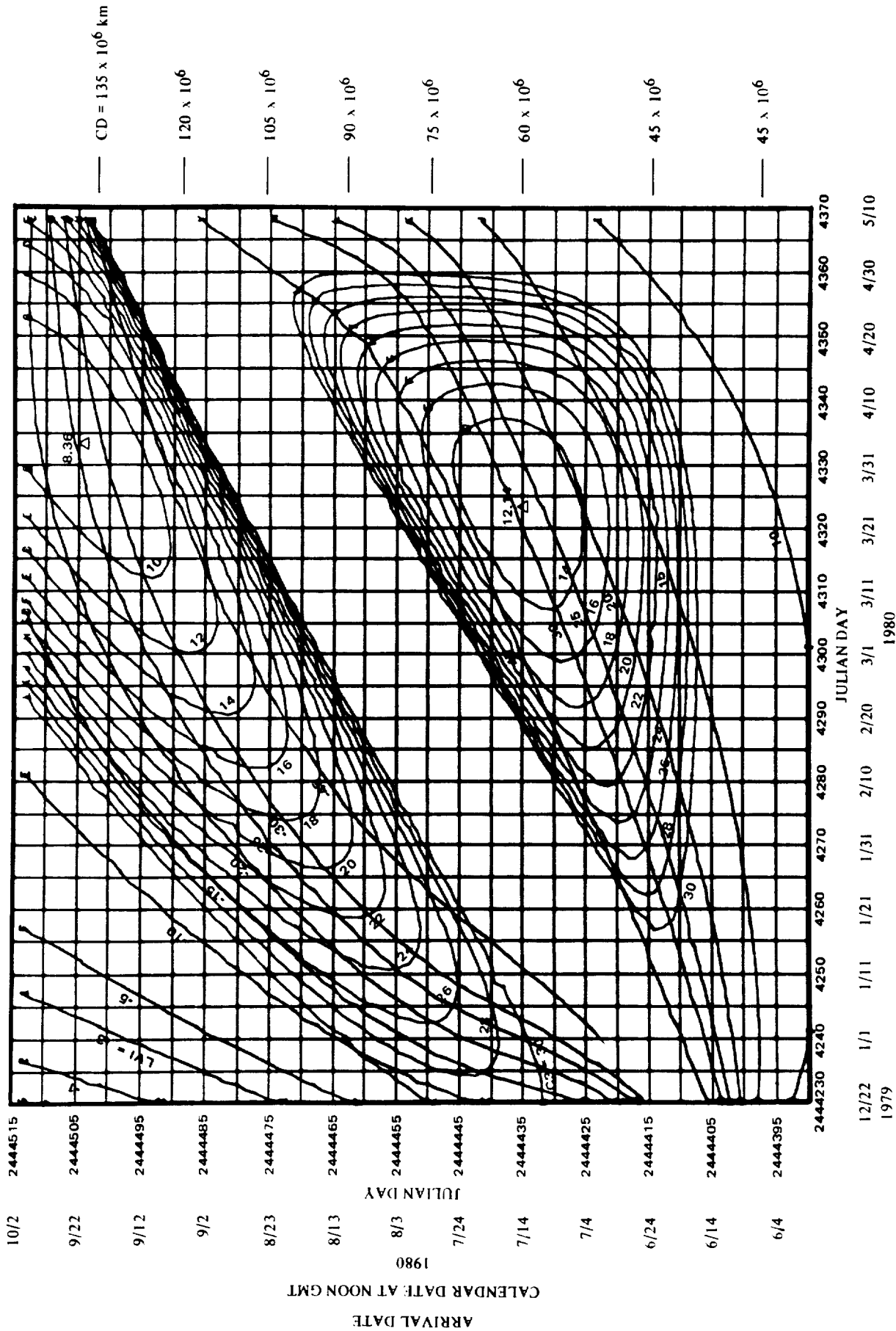
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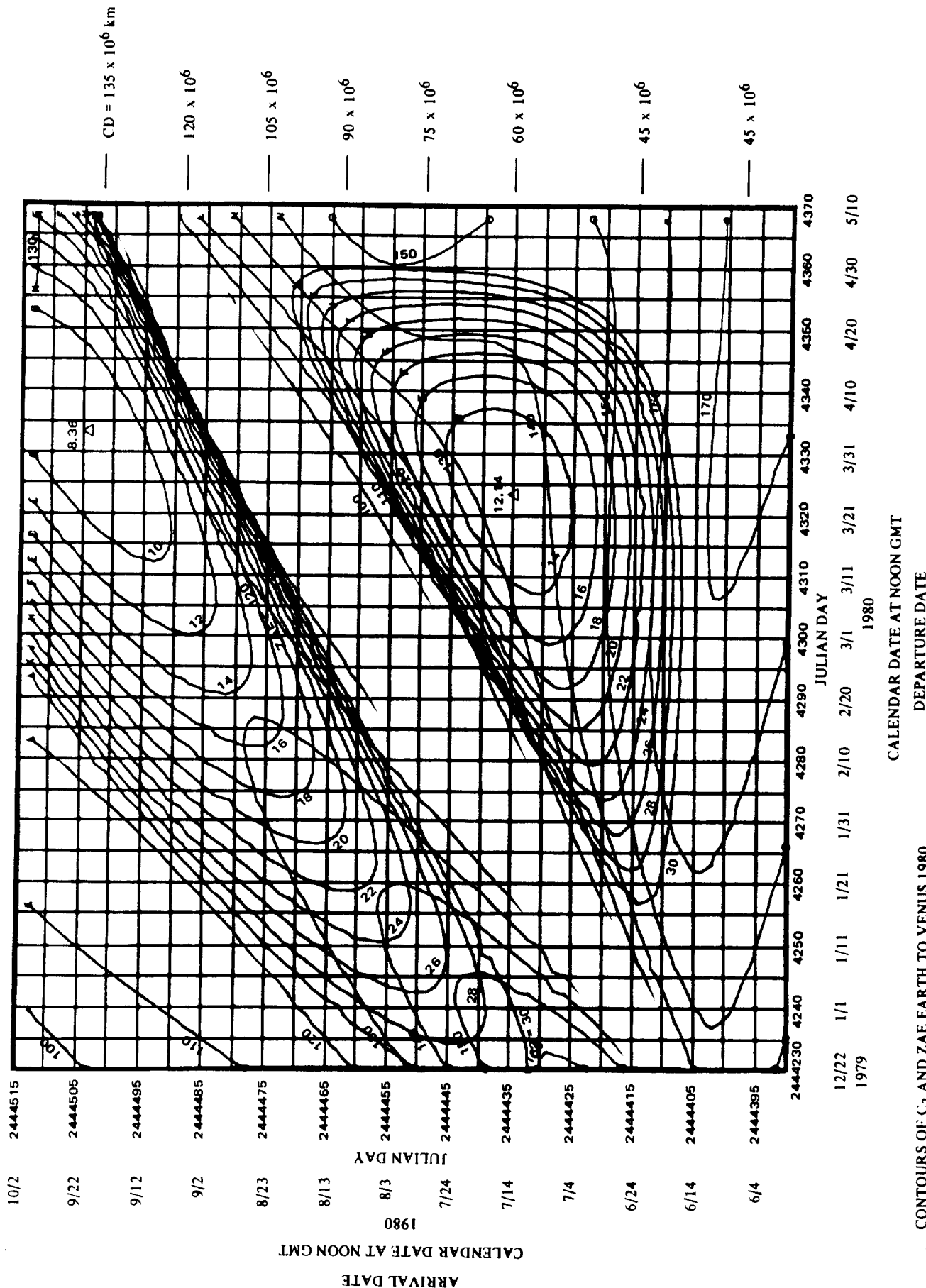
1980

12/22 1/1 1/11 1/21 1/31 2/10 2/20 3/1 3/11 3/21 3/31 4/10 4/20 4/30 5/10
 1979

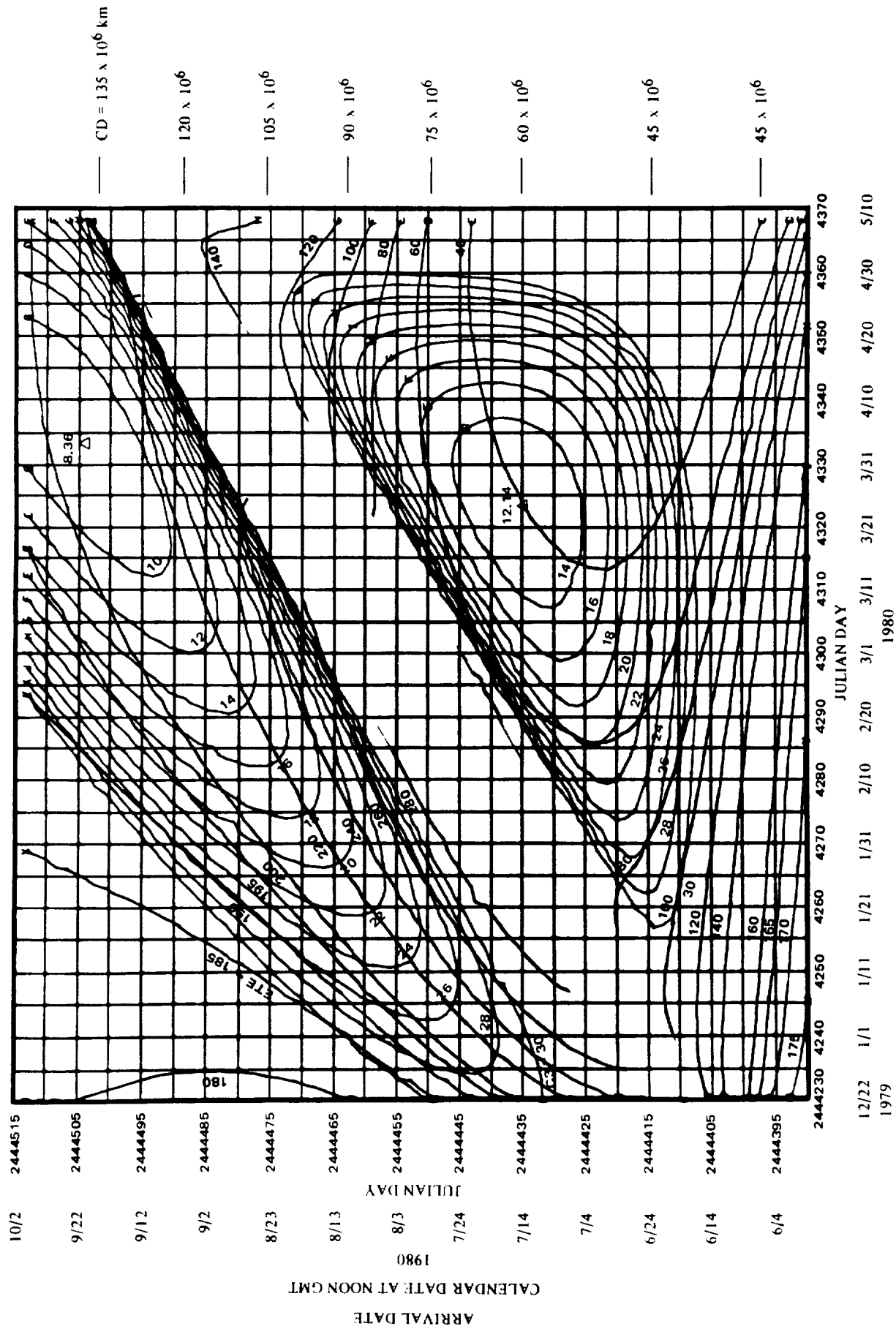




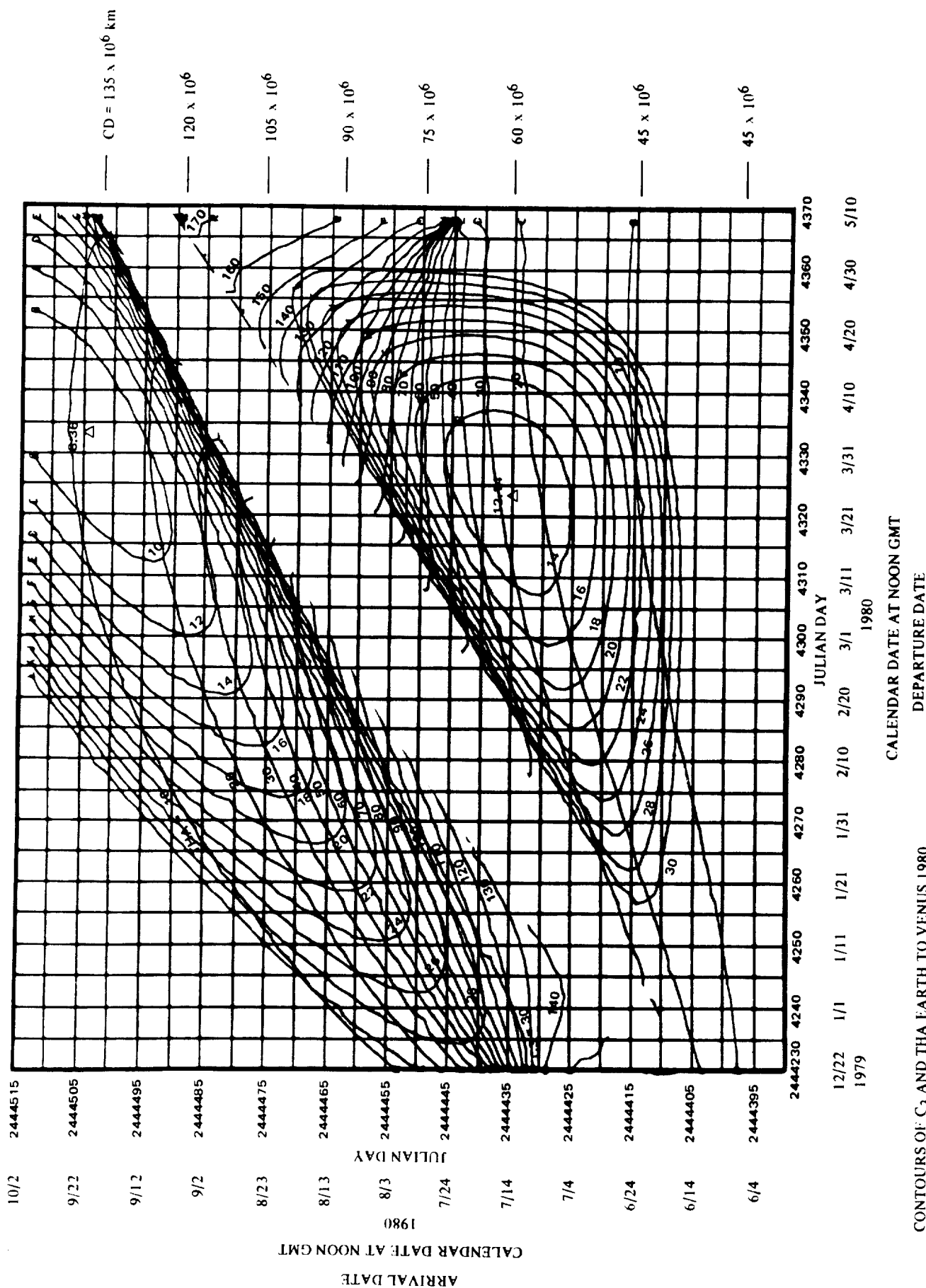
CONTOURS OF C_3 AND LVI EARTH TO VENUS 1980

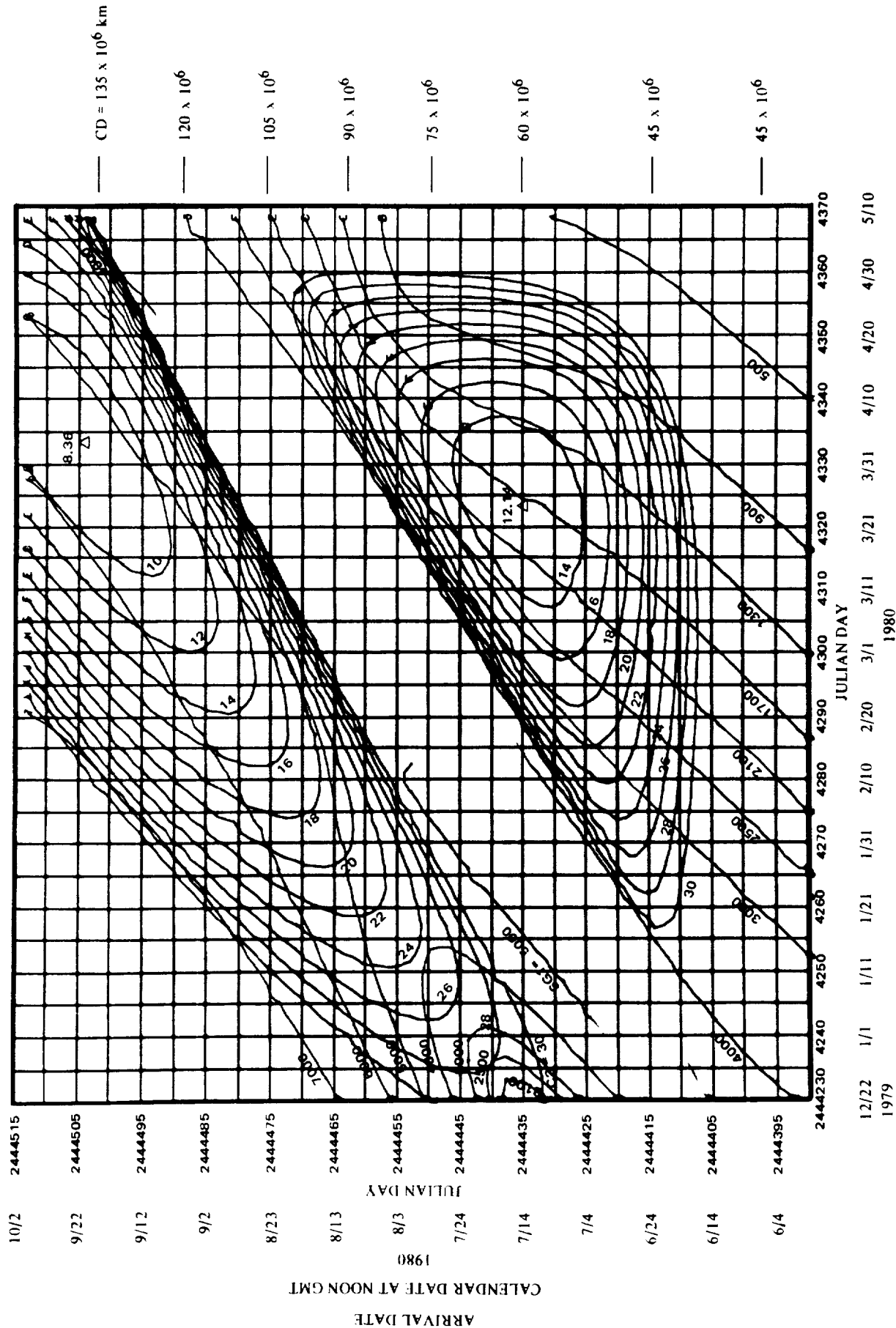


CONTOURS OF C_3 AND ZAE EARTH TO VENUS 1980



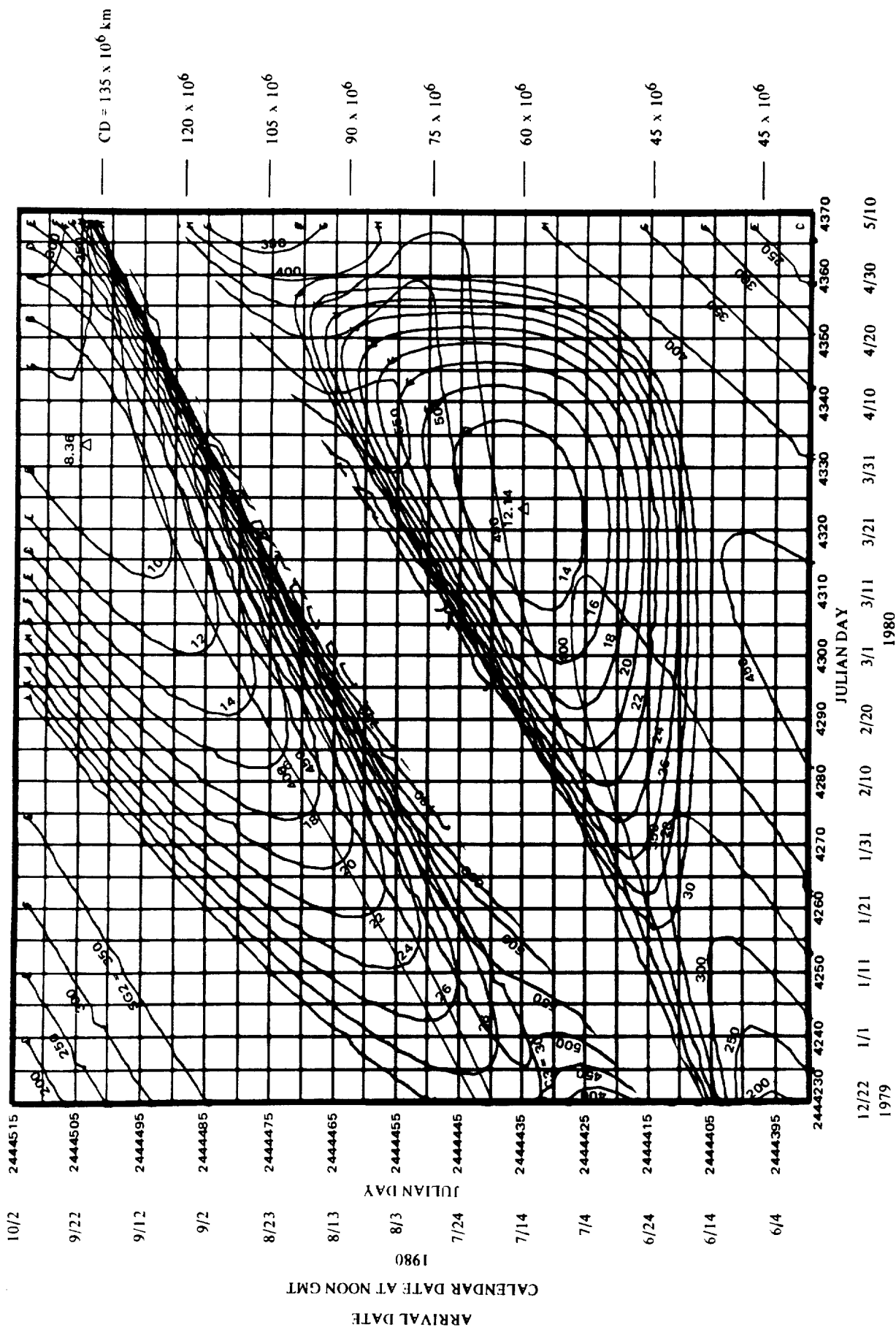
CONTOURS OF C_3 AND ETE EARTH TO VENUS 1980

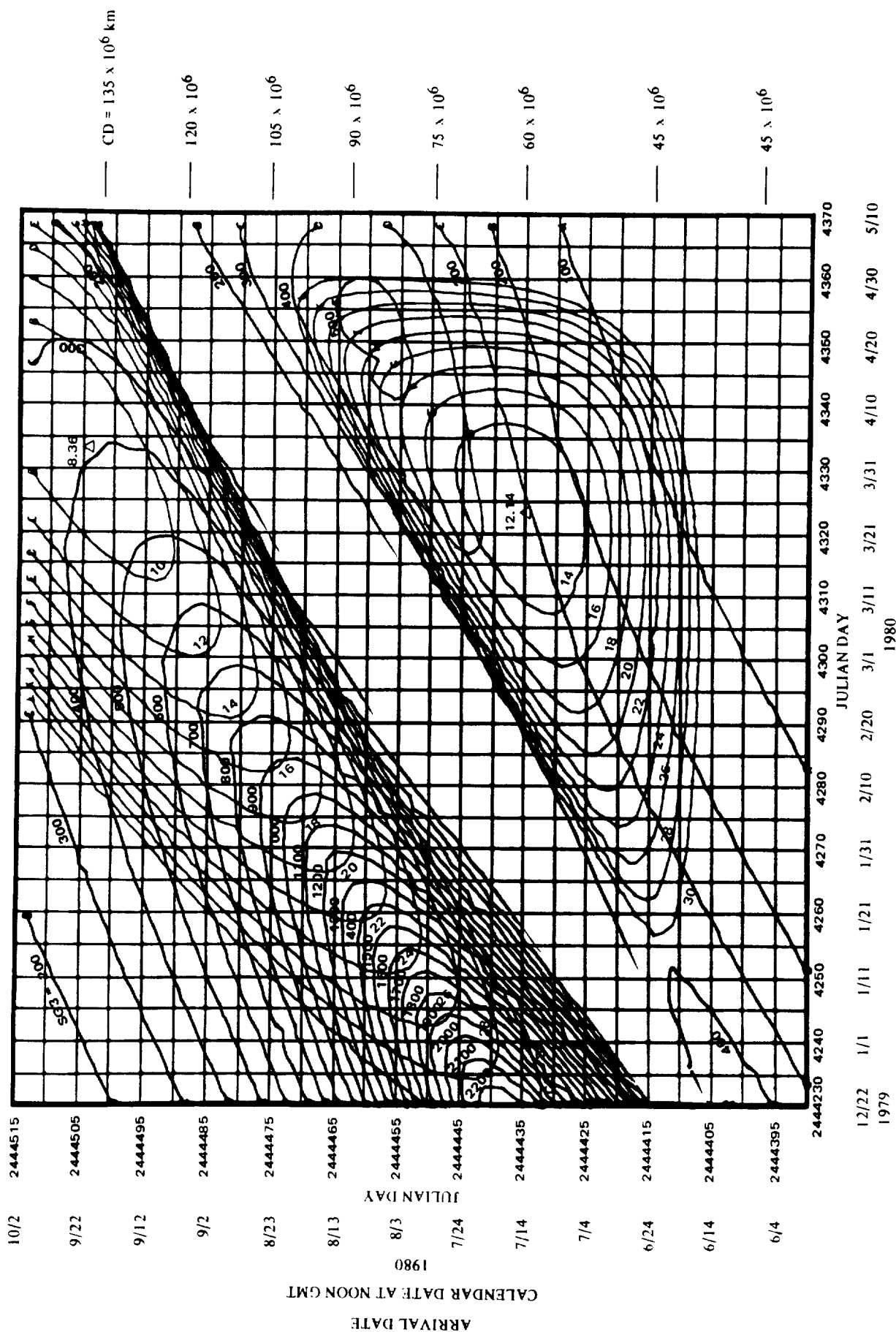




CONTOURS OF C_3 AND SG1 EARTH TO VENUS 1980

CALENDAR DATE AT NOON GMT
DEPARTURE DATE

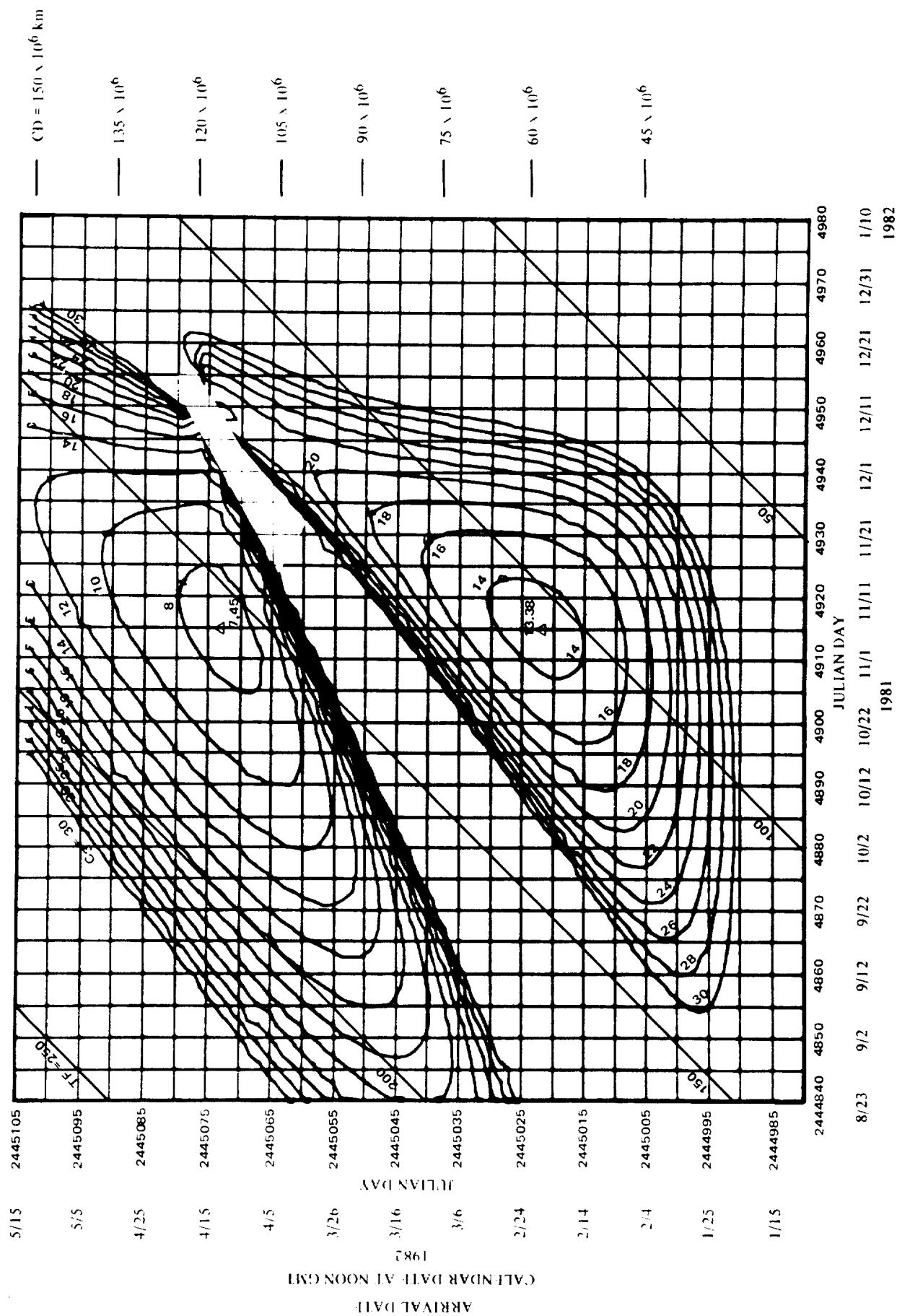


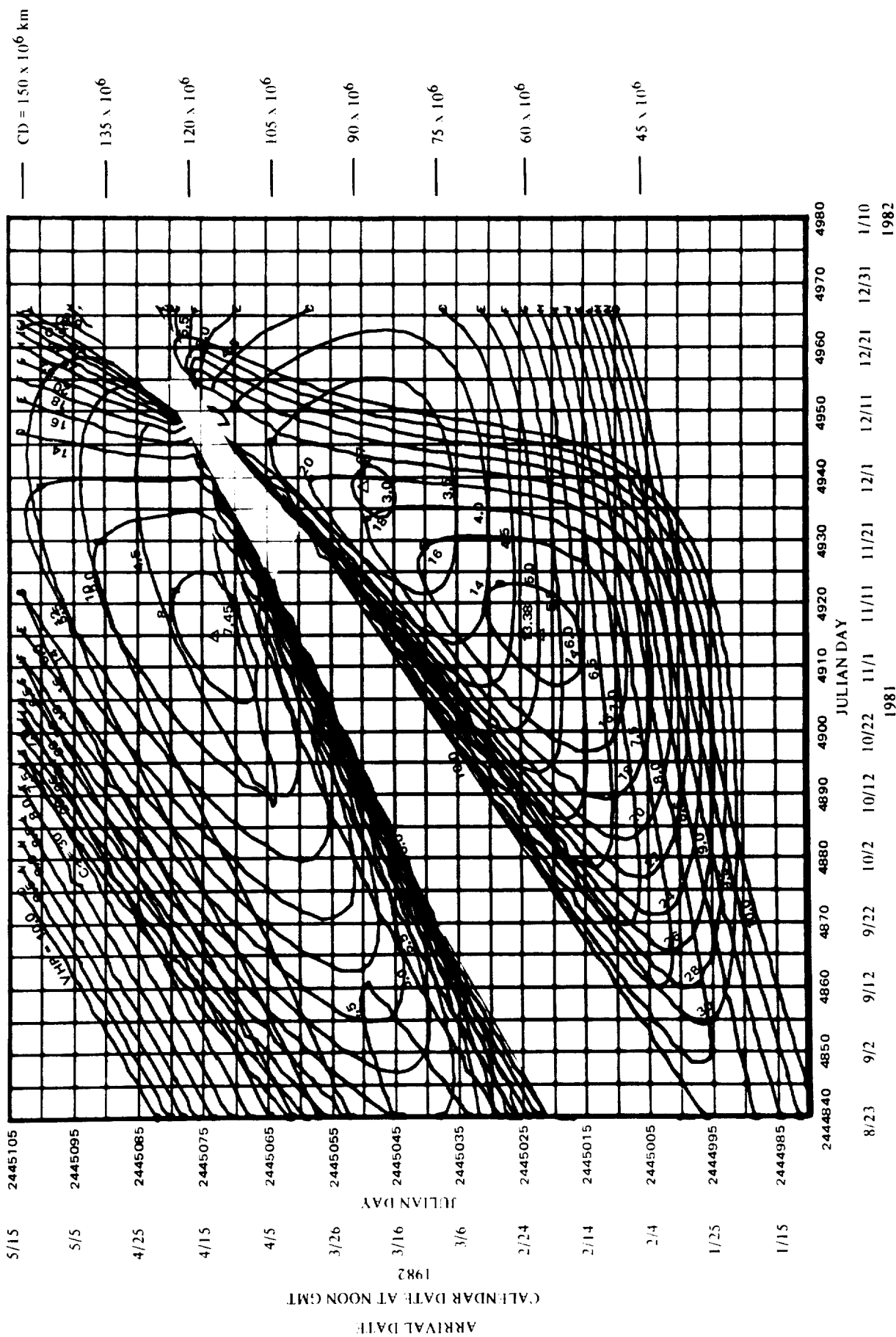


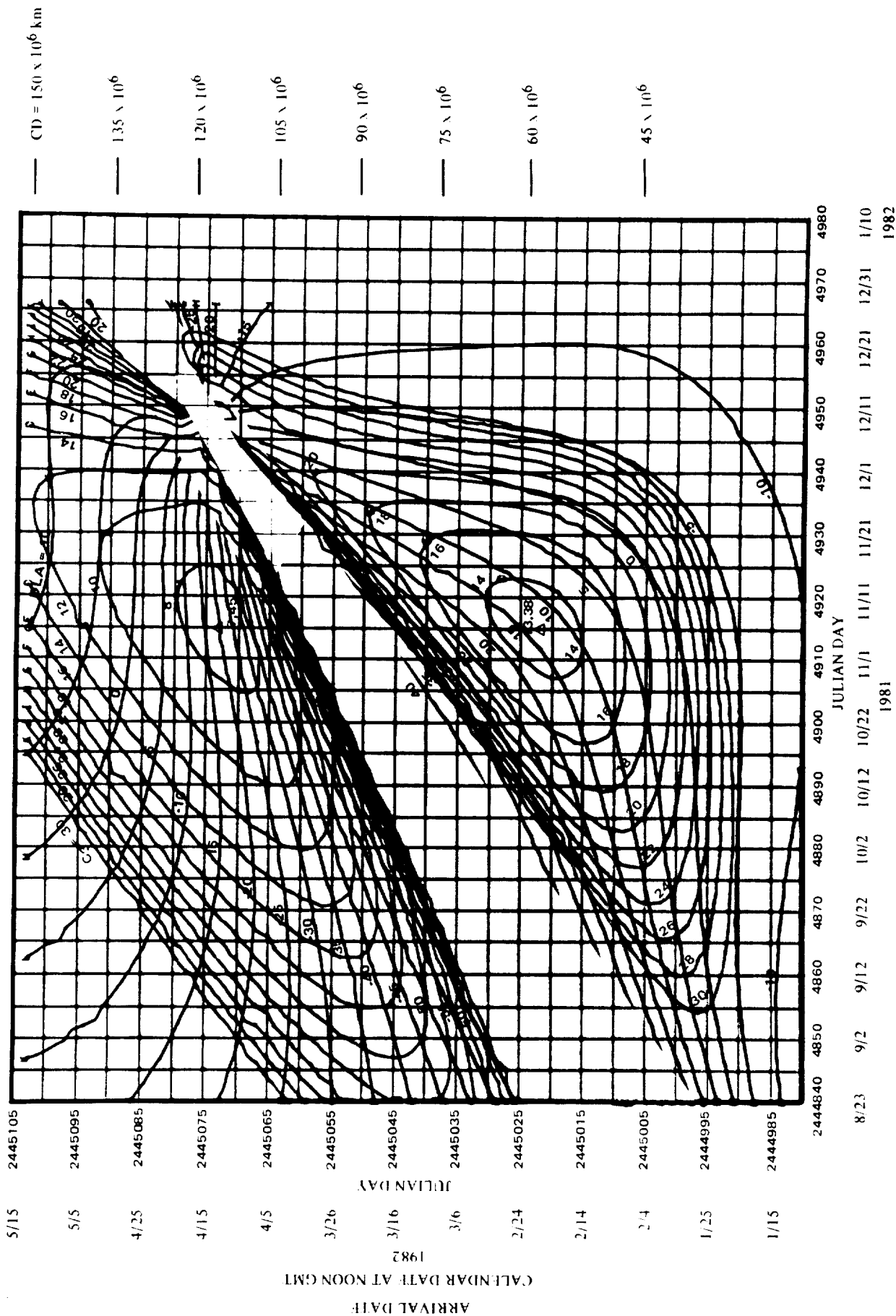
CONTOURS OF C_3 AND SG3 EARTH TO VENUS 1980

CALENDAR DATE AT NOON GMT
DEPARTURE DATE

1980







CONTOURS OF C₃ AND DLA EARTH TO VENUS 1981-82

— $CD = 150 \times 10^6$ km

— 135×10^6

— 120×10^6

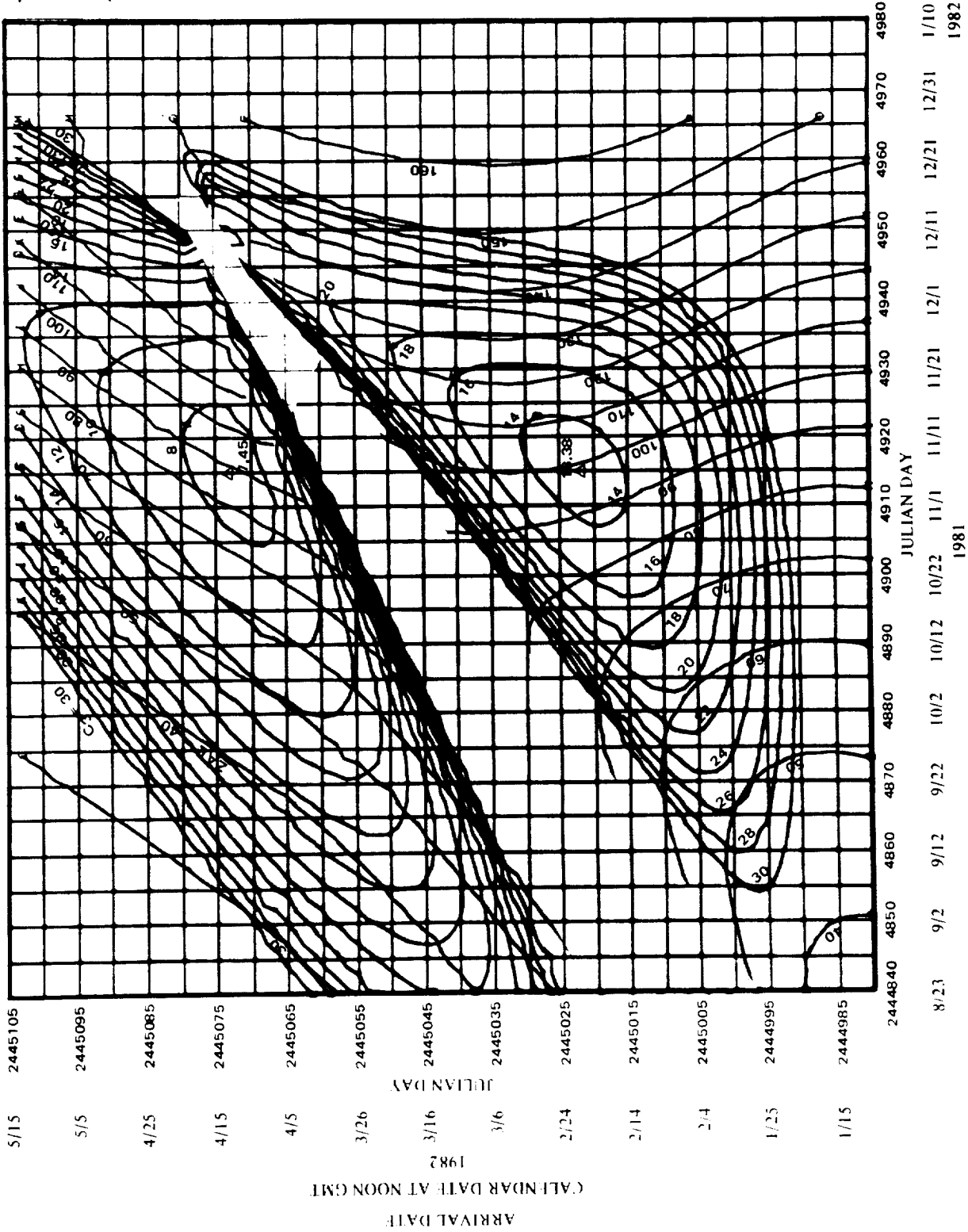
— 105×10^6

— 90×10^6

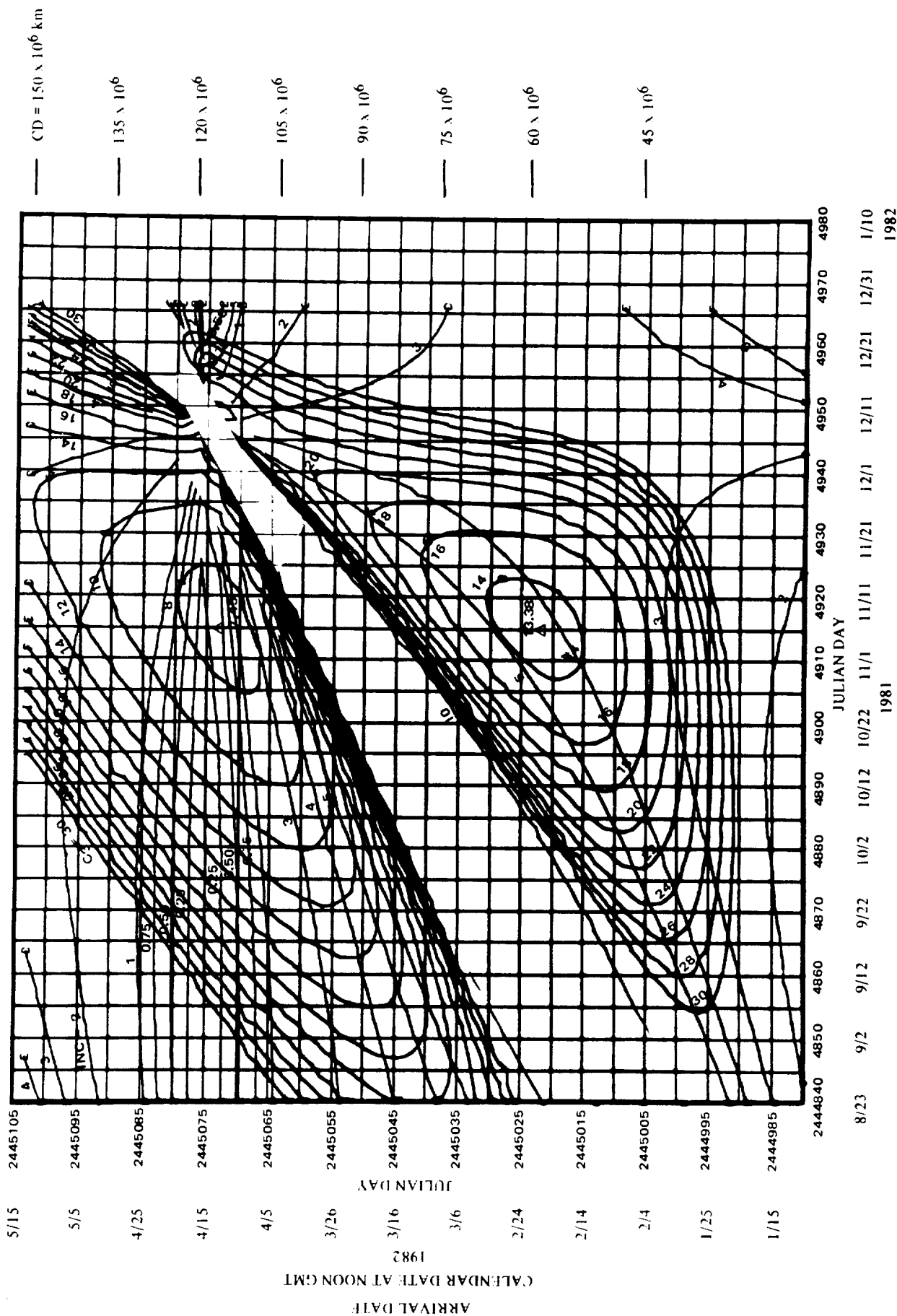
— 75×10^6

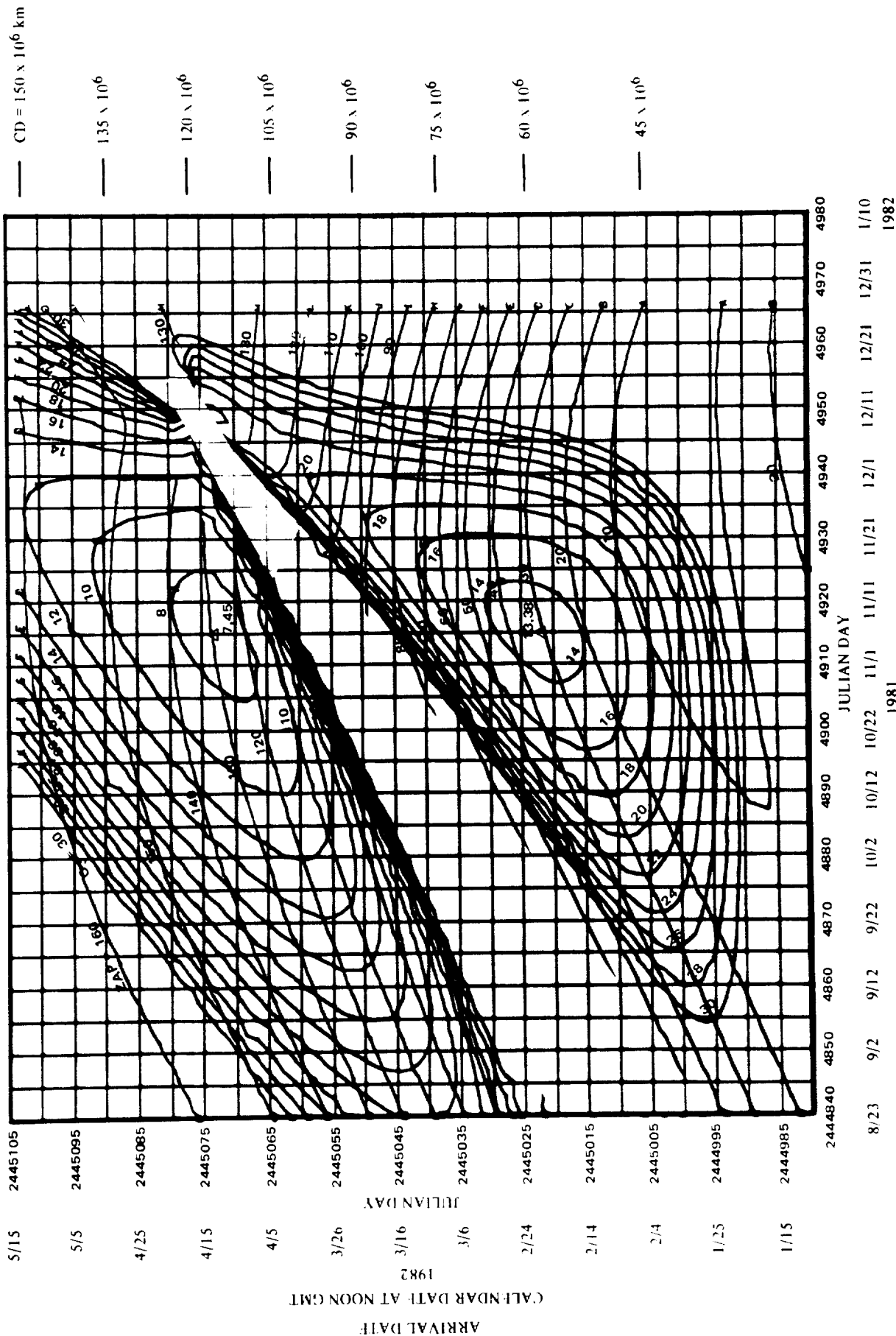
— 60×10^6

— 45×10^6

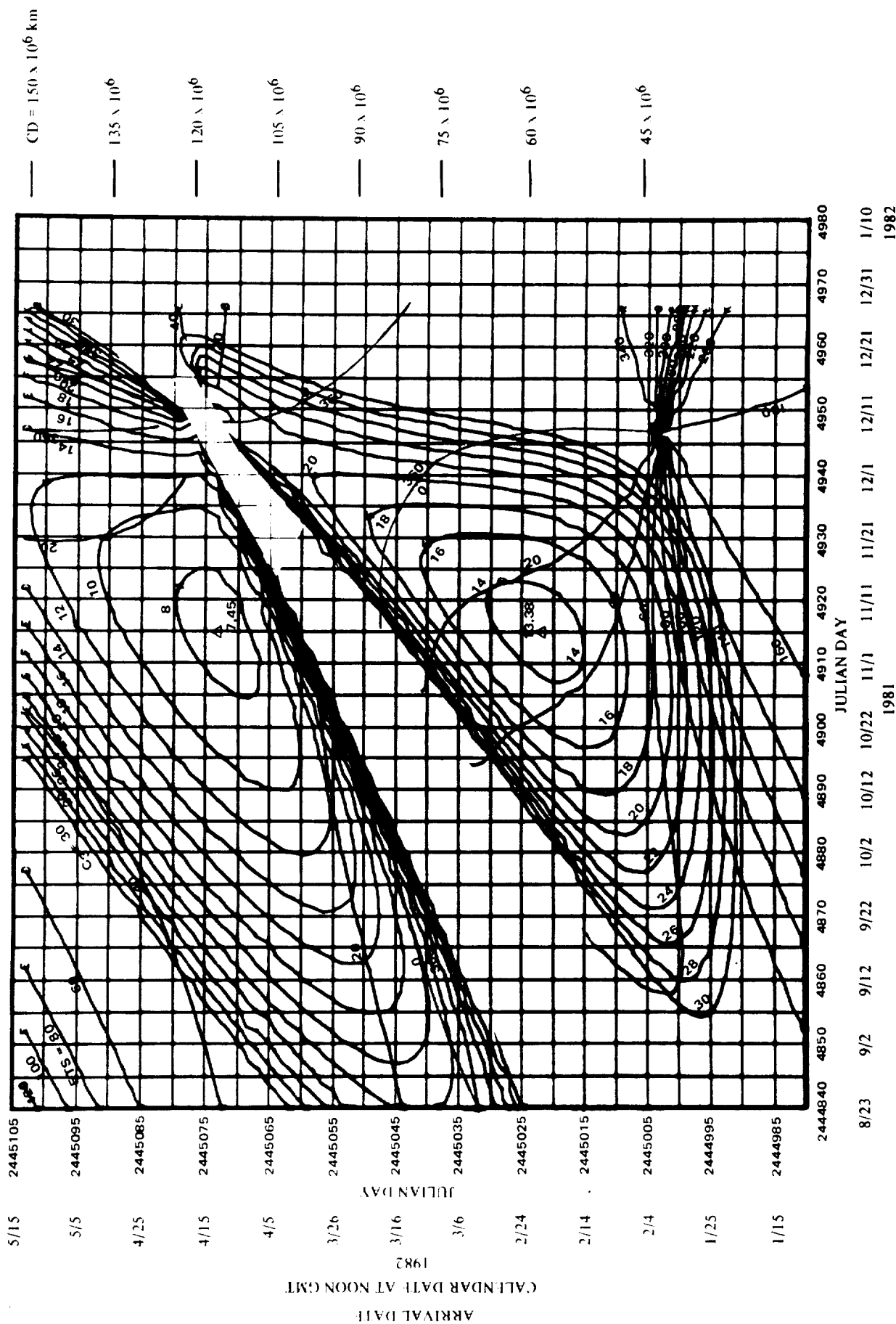


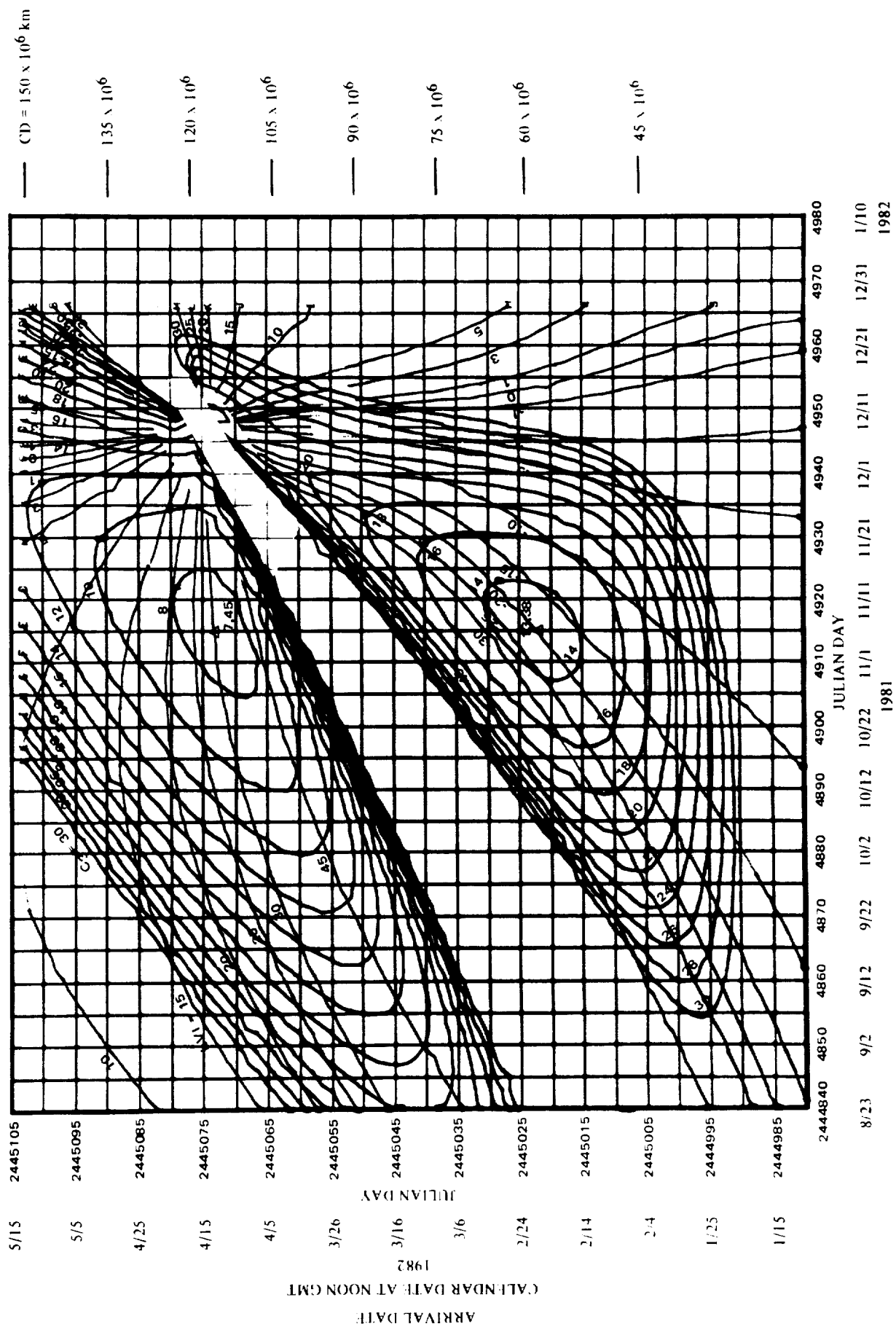
CONTOURS OF C_3 AND ZAL EARTH TO VENUS 1981 82

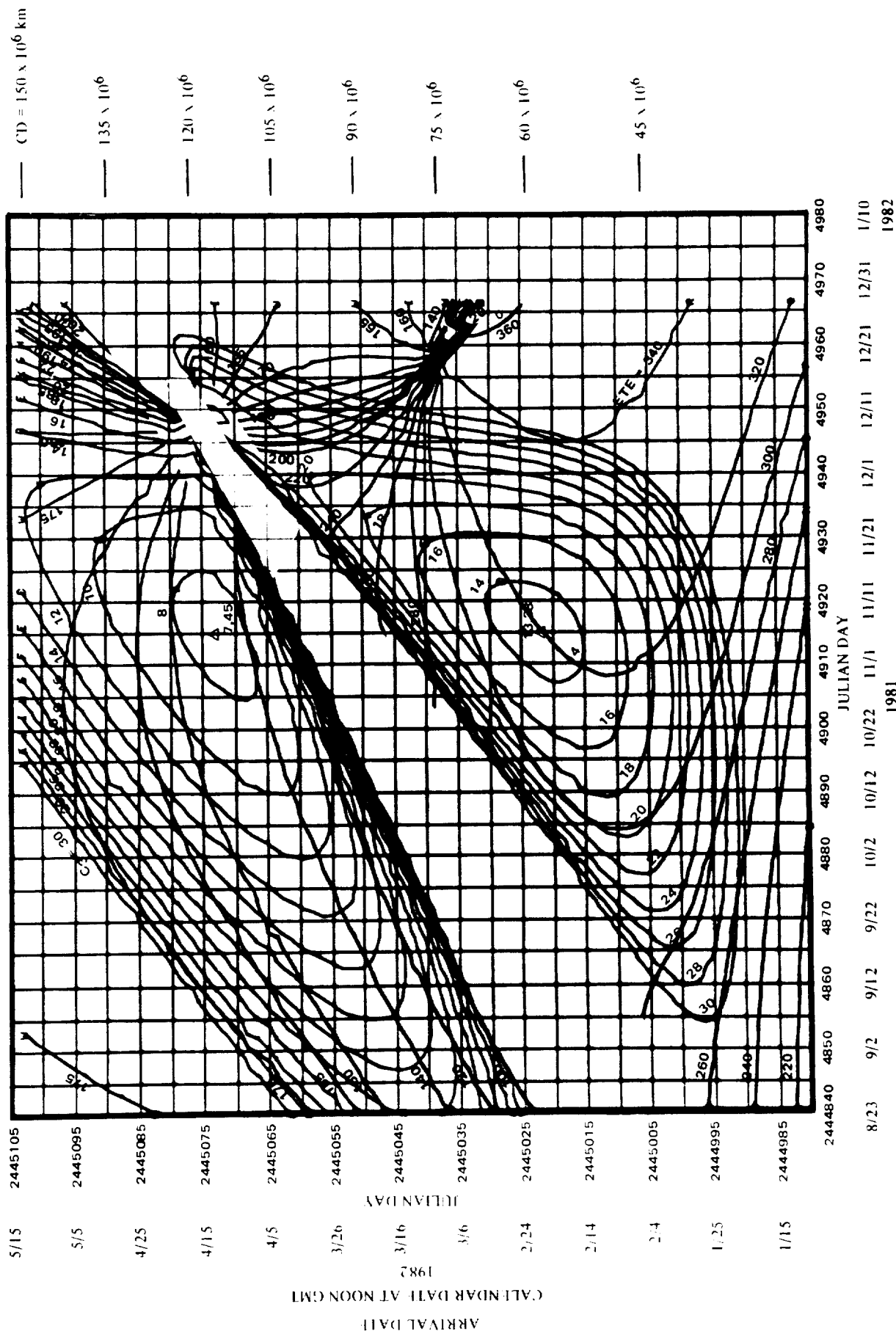




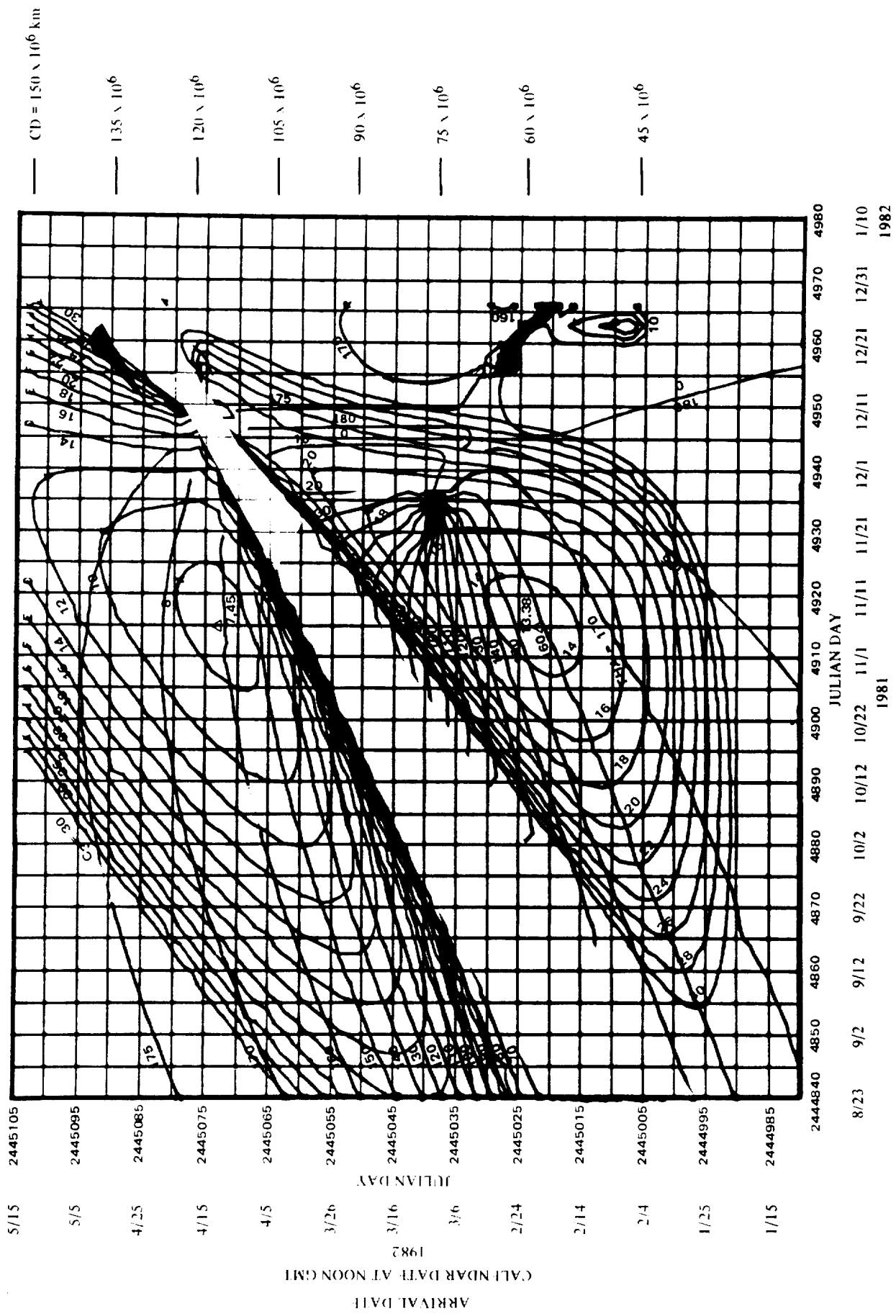
CONTOURS OF C_3 AND ZAP EARTH TO VENUS 1981-82







CONTOURS OF C_3 AND ETE EARTH TO VENUS 1981-82

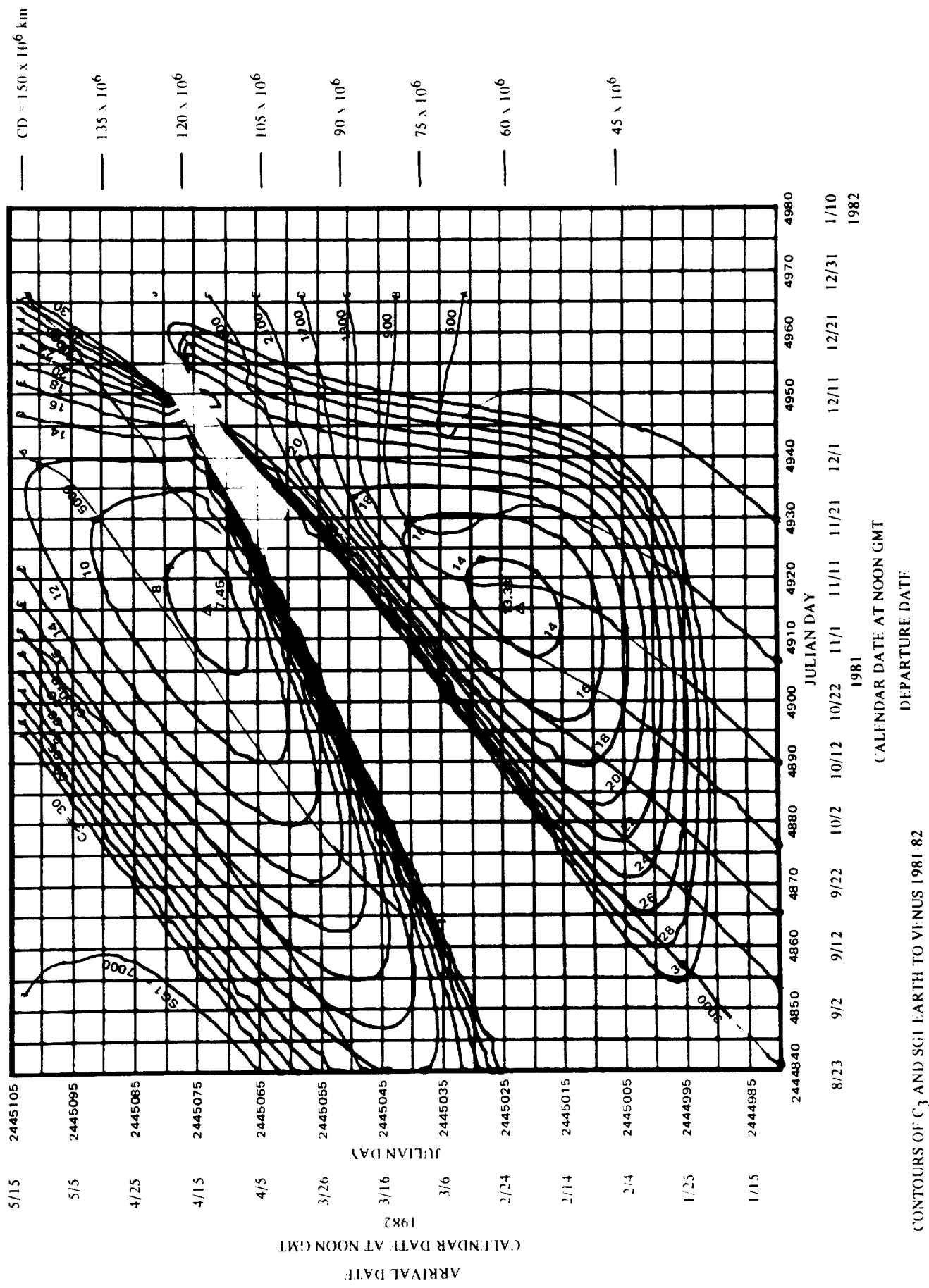


CONTOURS OF C_3 AND THA EARTH TO VENUS 1981-82

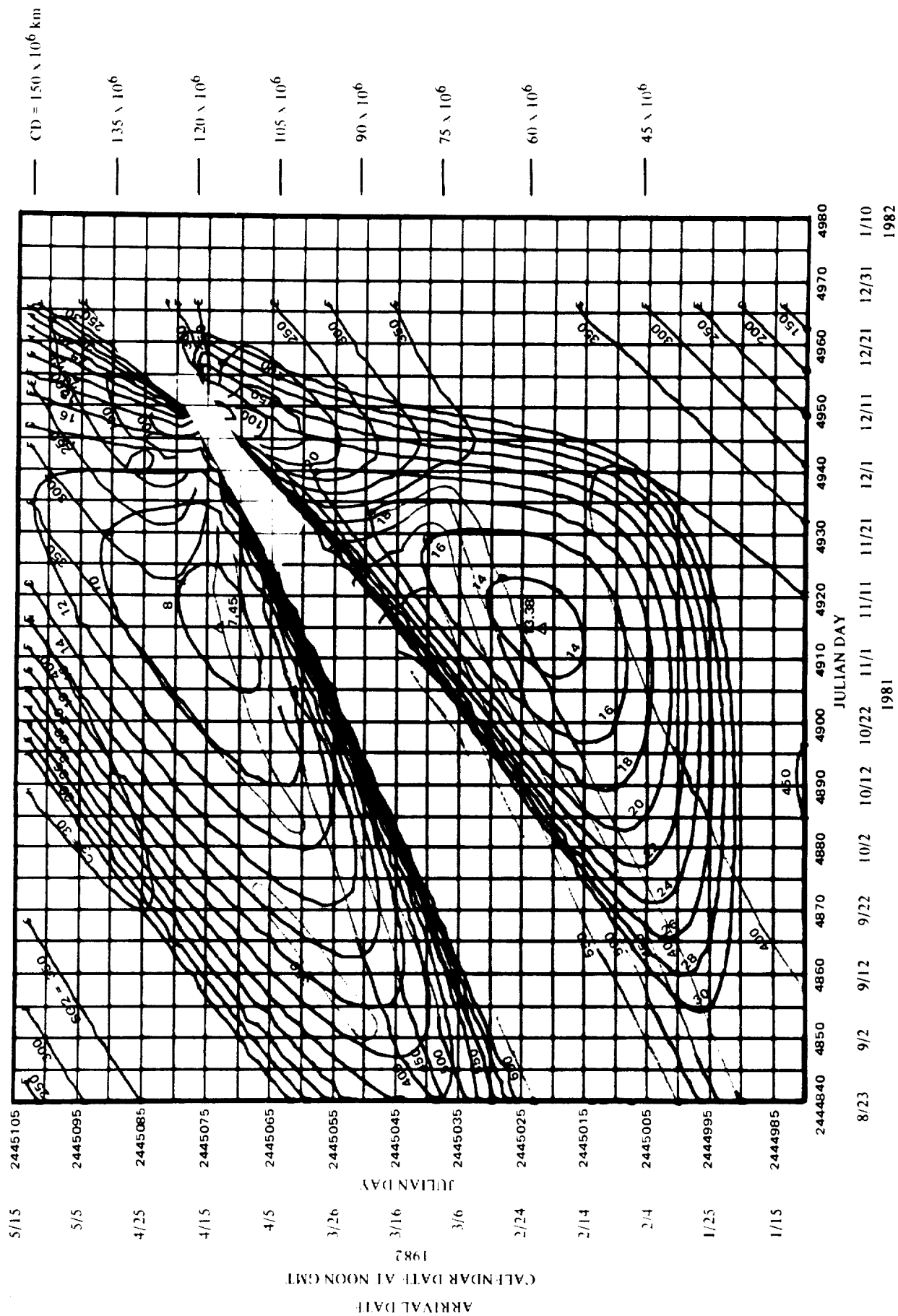
CALENDAR DATE AT NOON GMT

1981

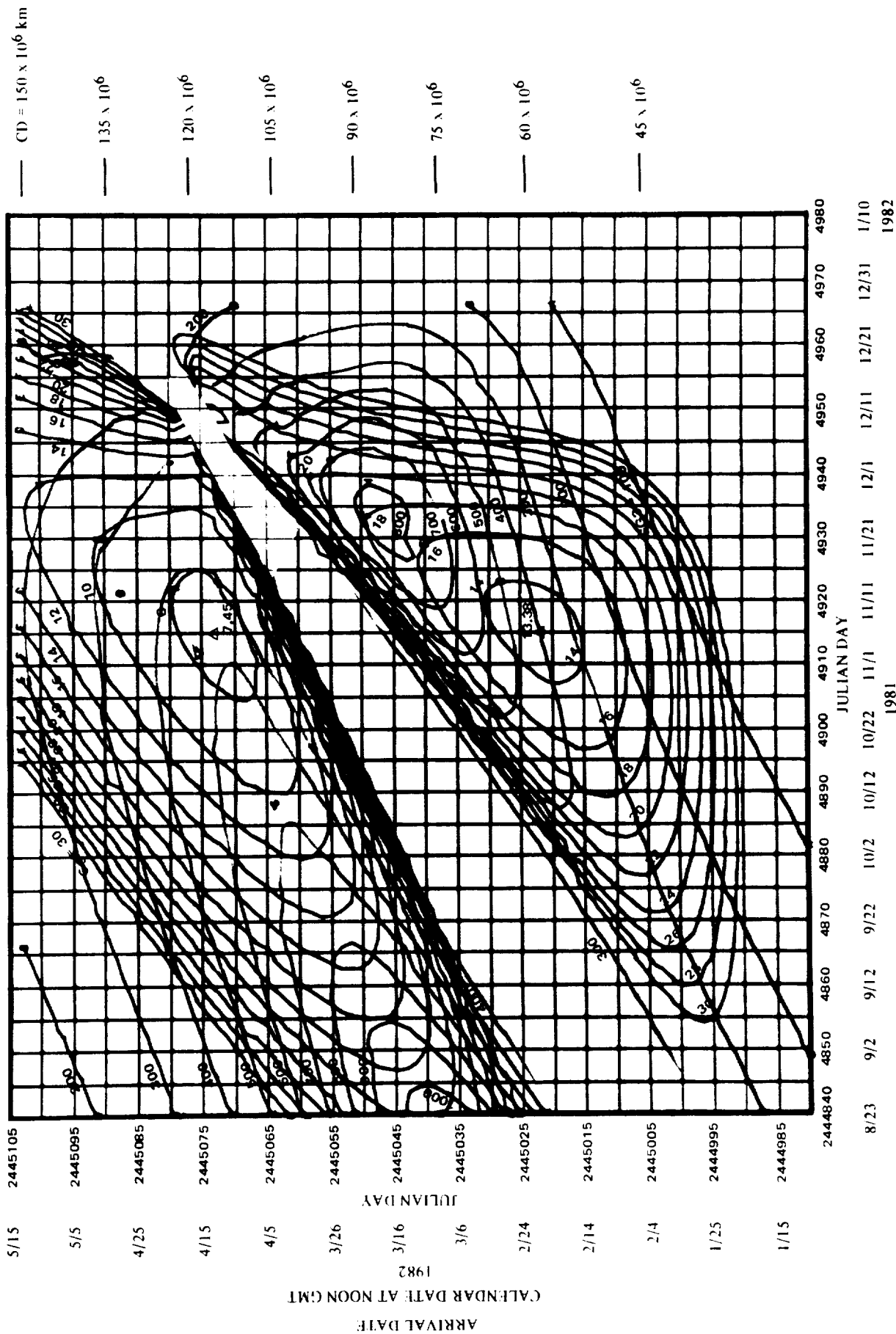
DEPARTURE DATE



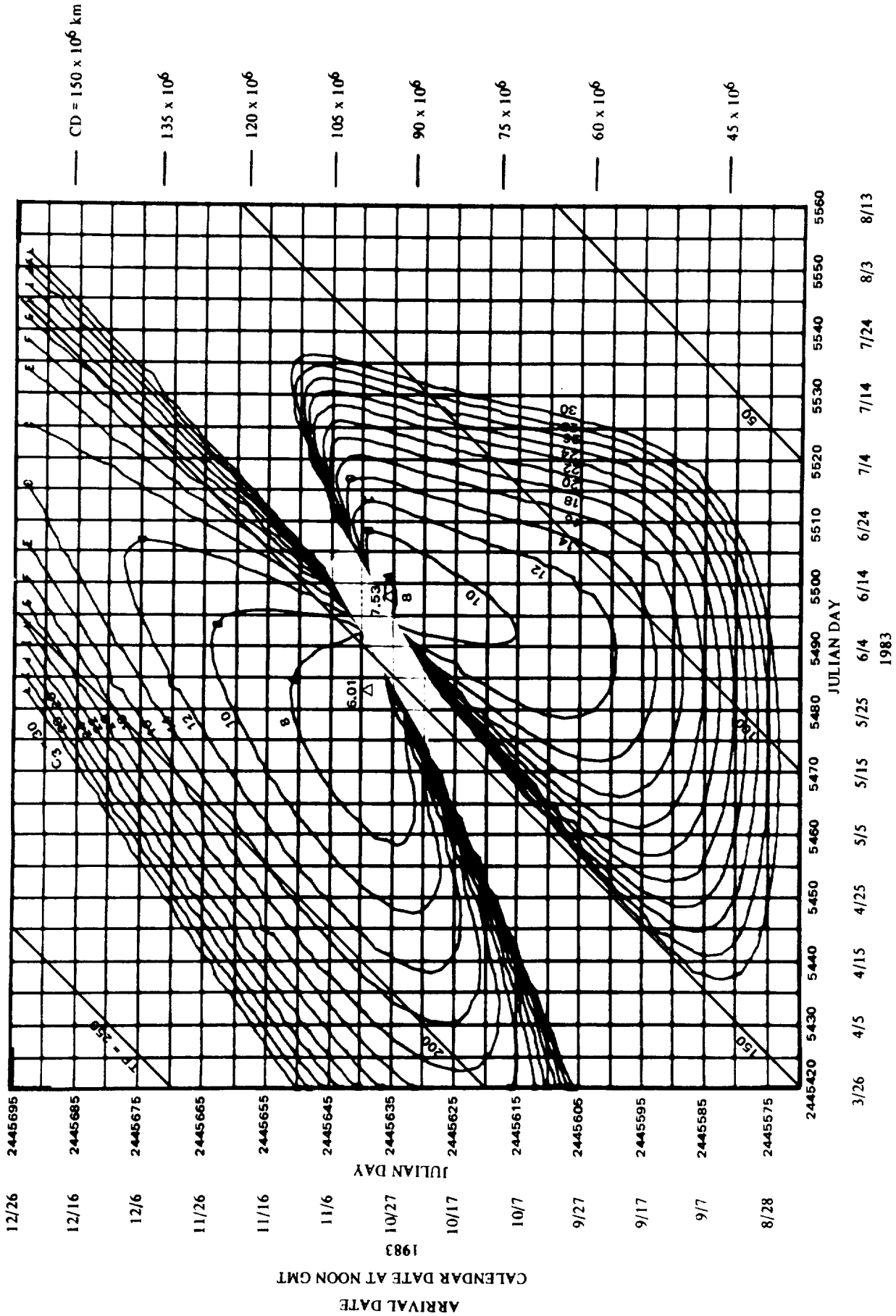
CONTOURS OF C₃ AND SGI EARTH TO VENUS 1981-82

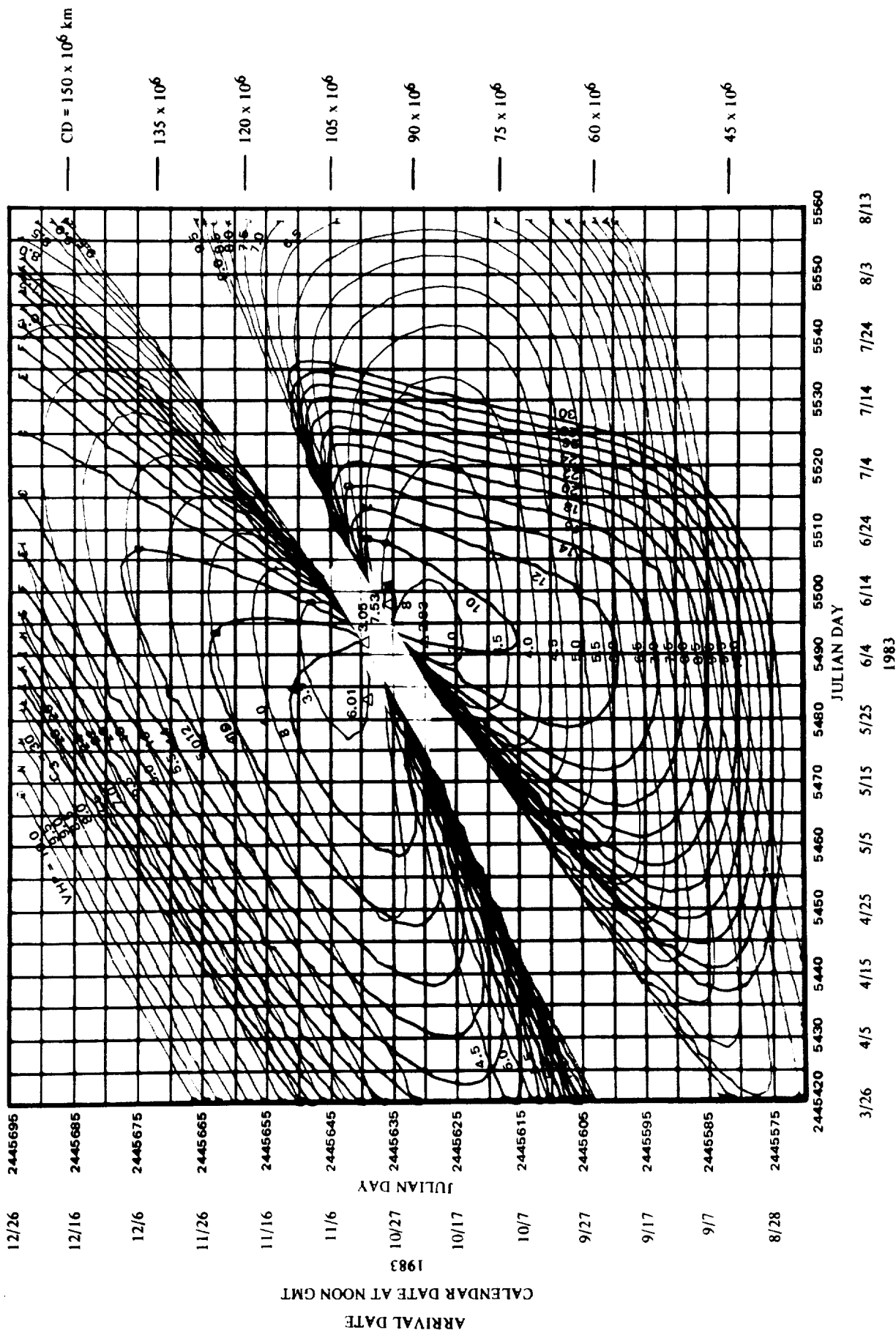


CONTOURS OF C_3 AND SG2 EARTH TO VENUS 1981-82

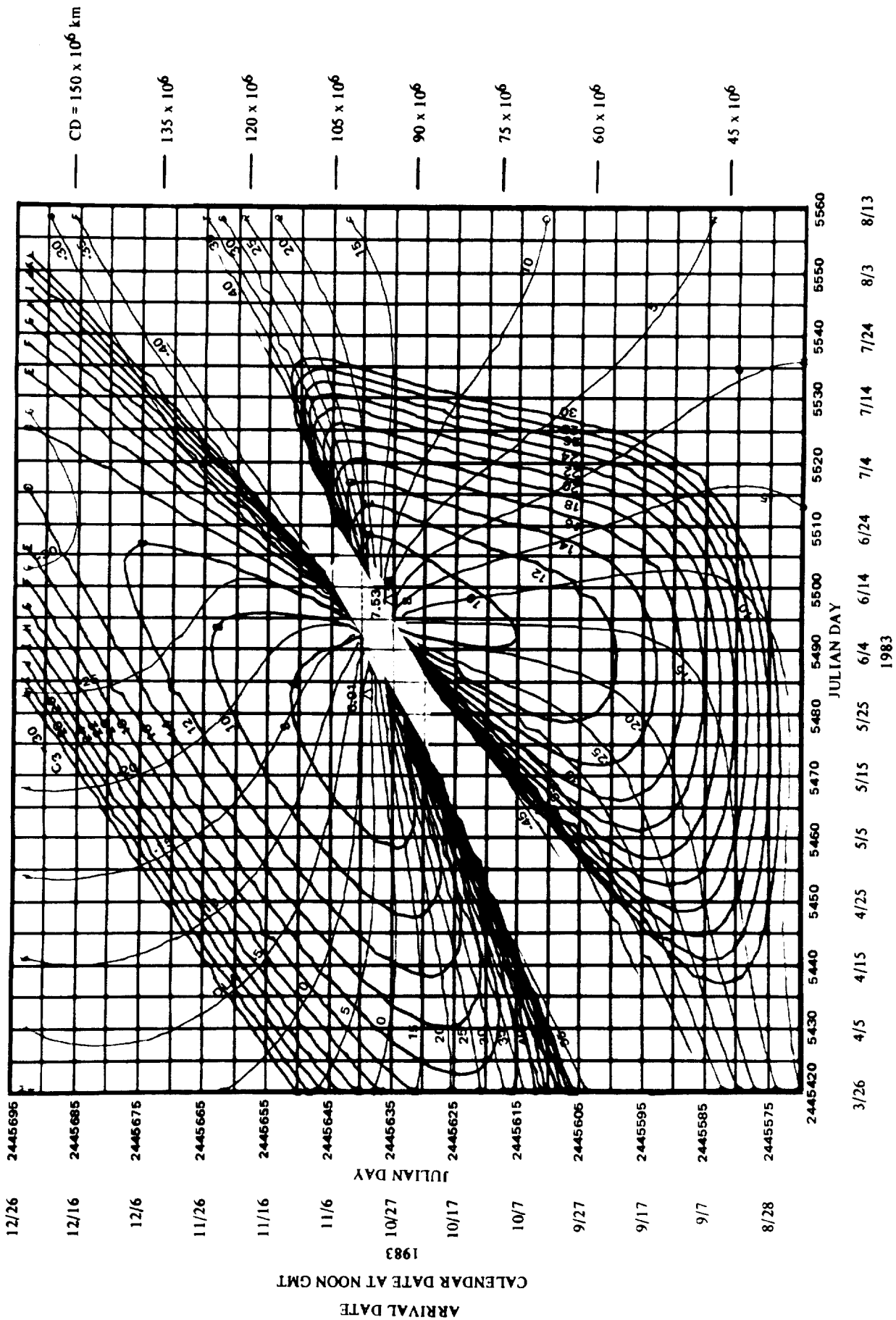


CONTOURS OF C_3 AND SG3 EARTH TO VENUS 1981-82

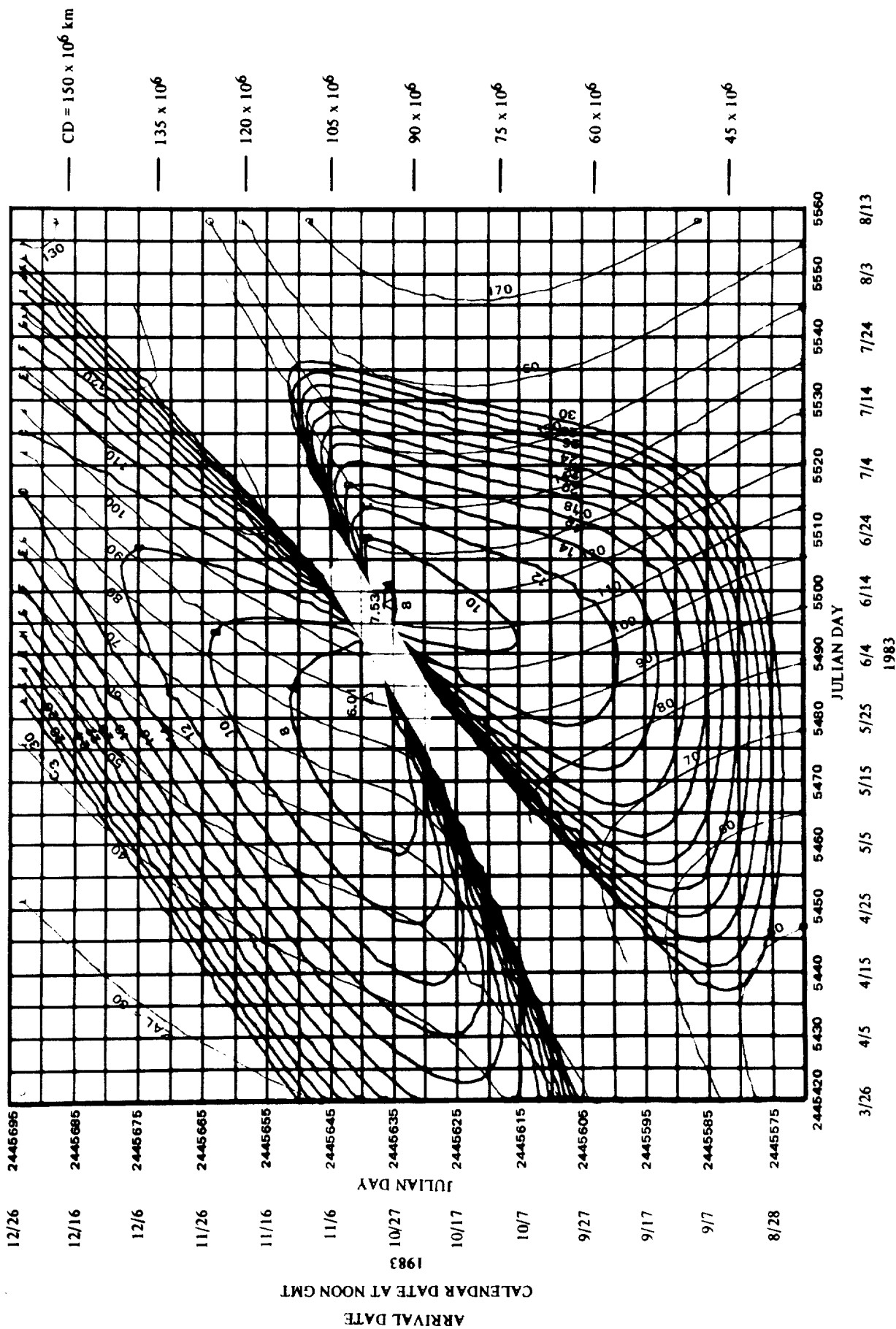




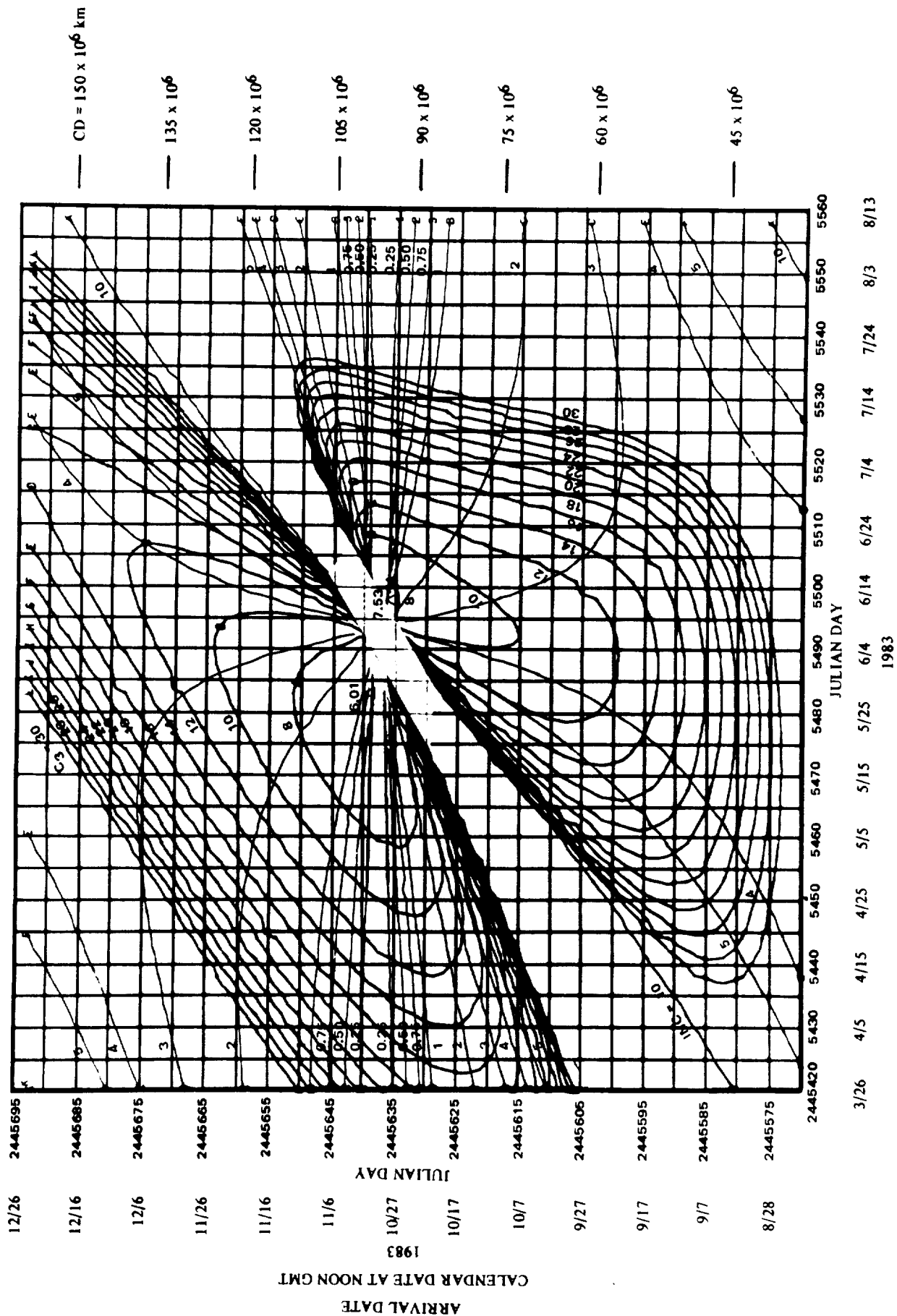
CONTOURS OF C₃ AND VHP EARTH TO VENUS 1983

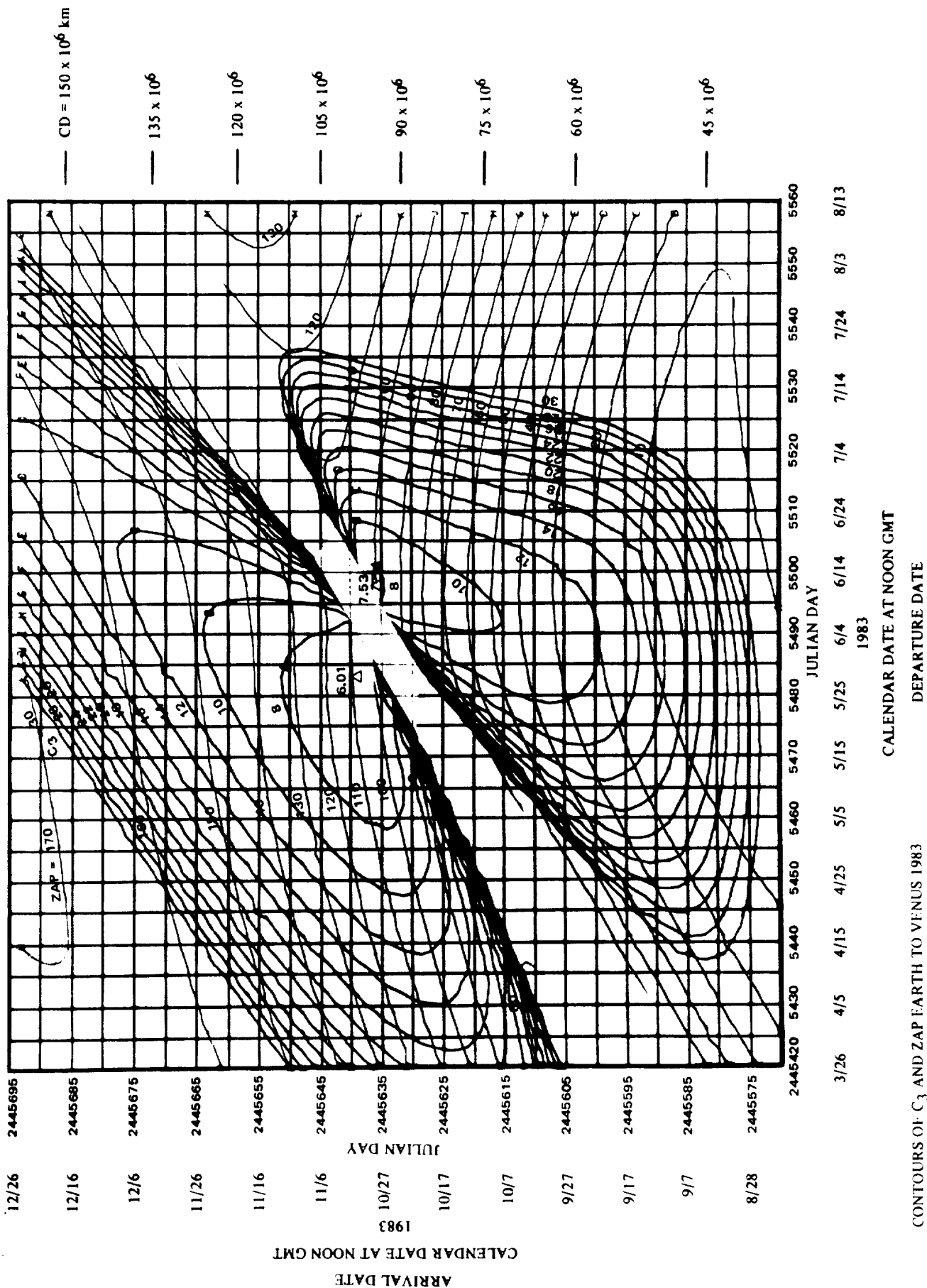


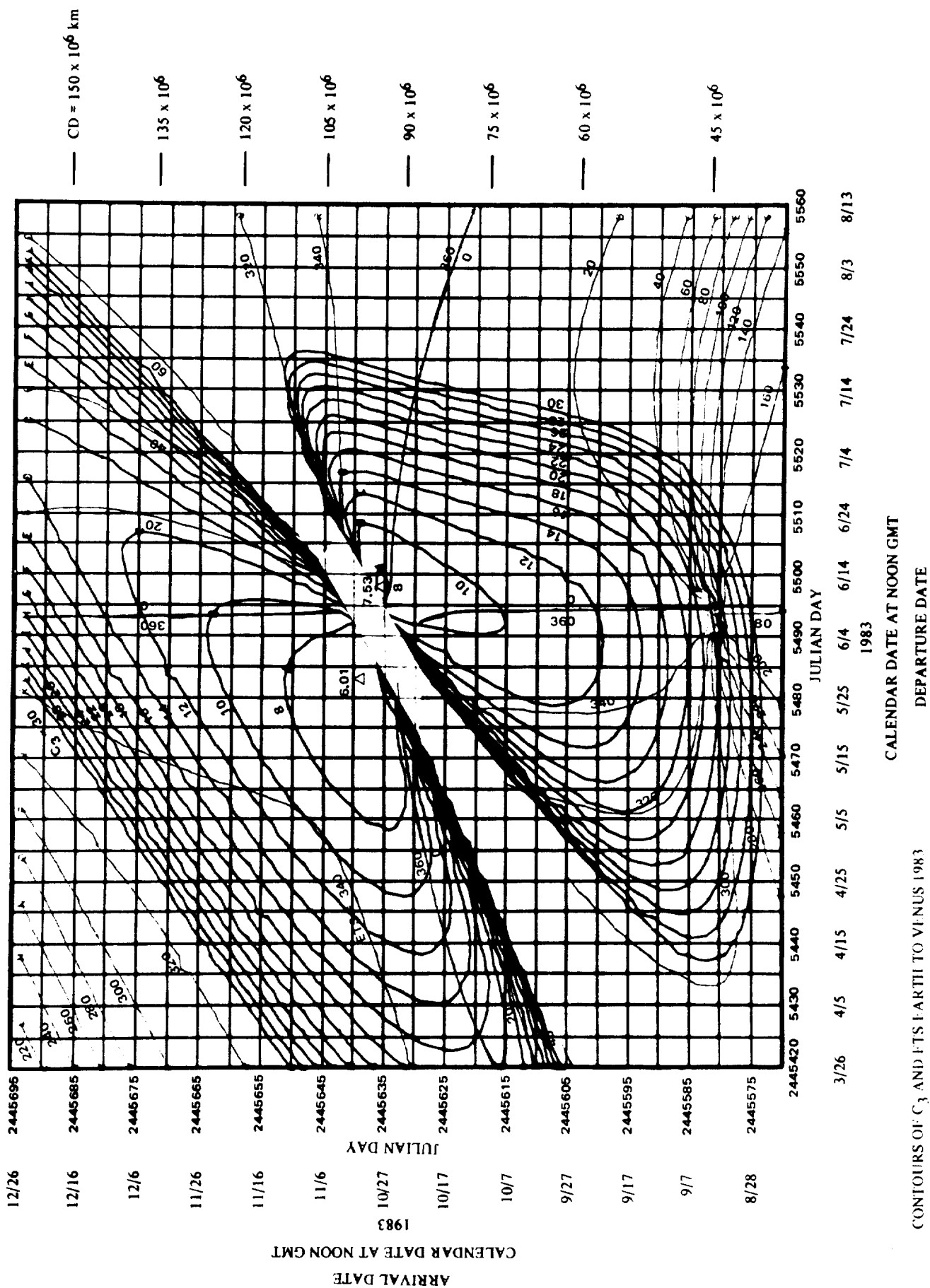
CONTOURS OF C_3 AND DLA EARTH TO VENUS 1983

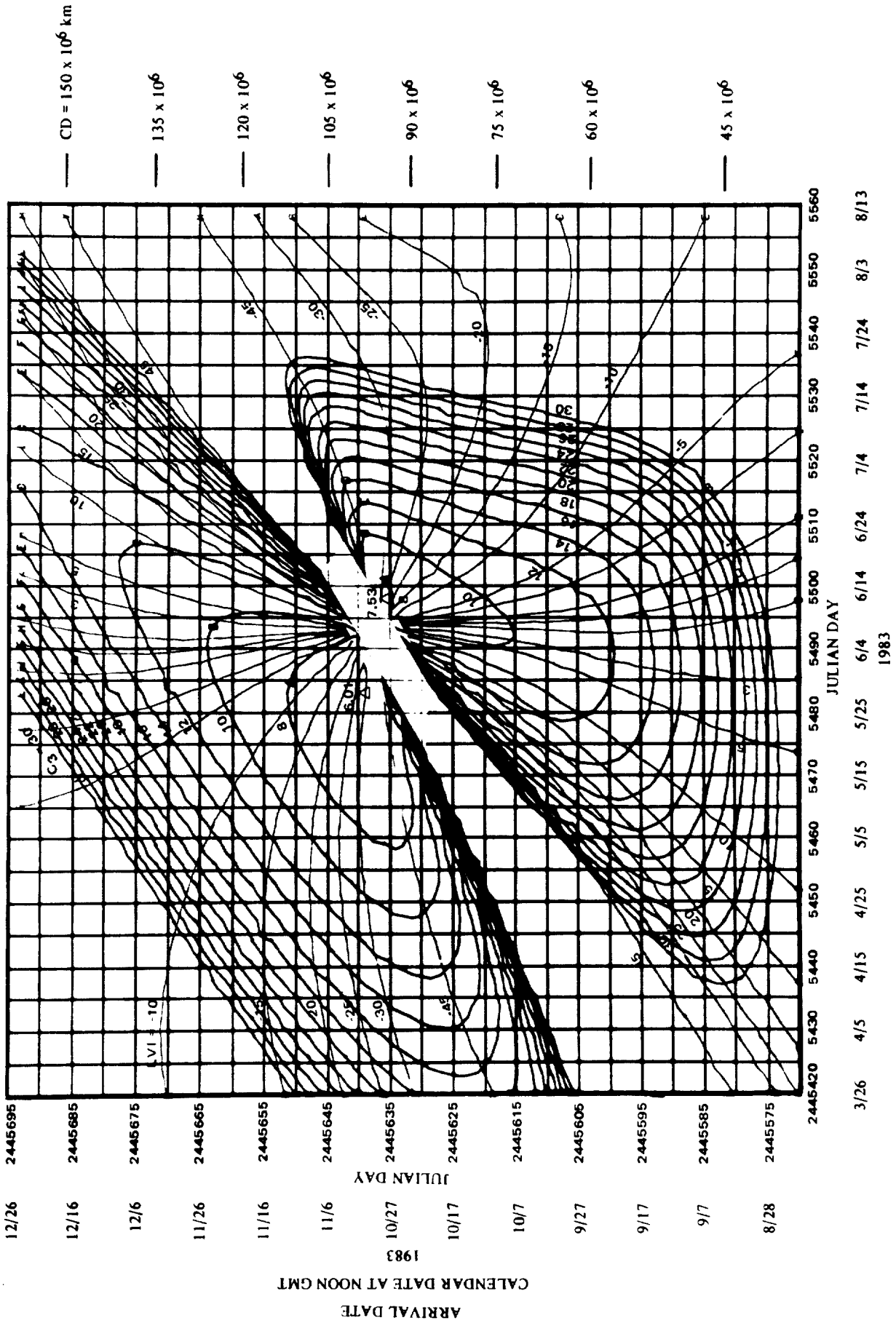


CONTOURS OF C_3 AND ZAL EARTH TO VENUS 1983

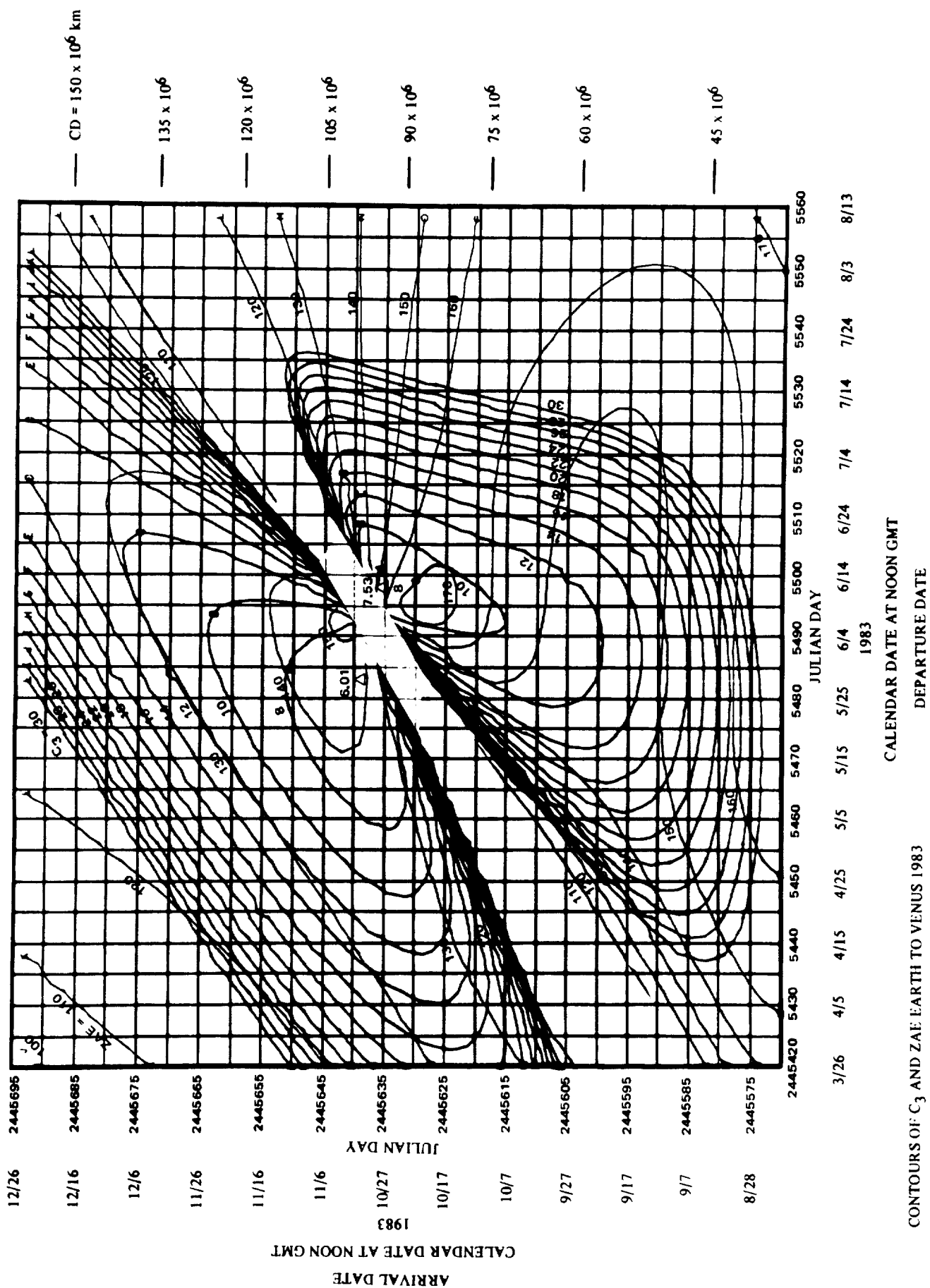


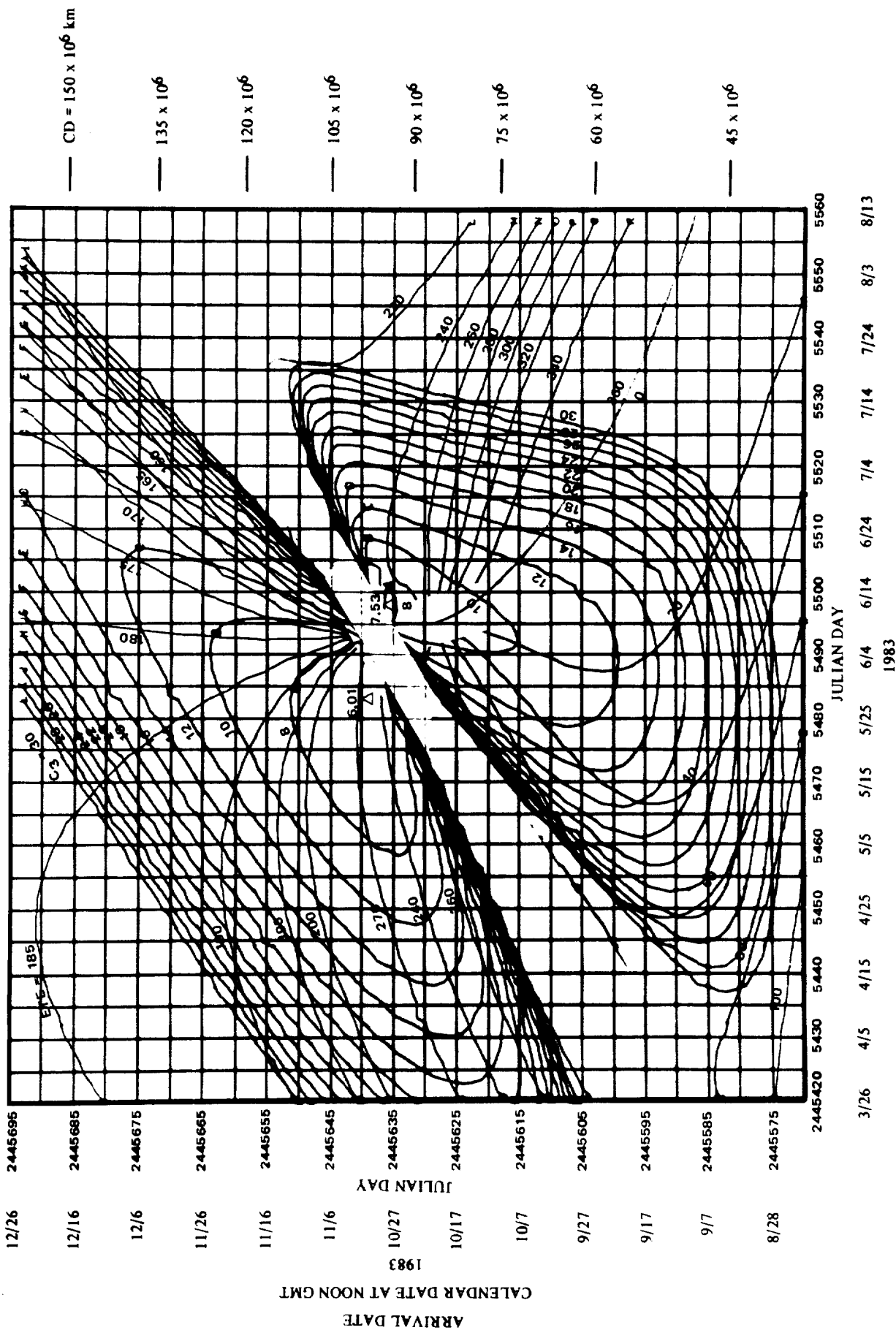






CONTOURS OF C_3 AND LVI EARTH TO VENUS 1983

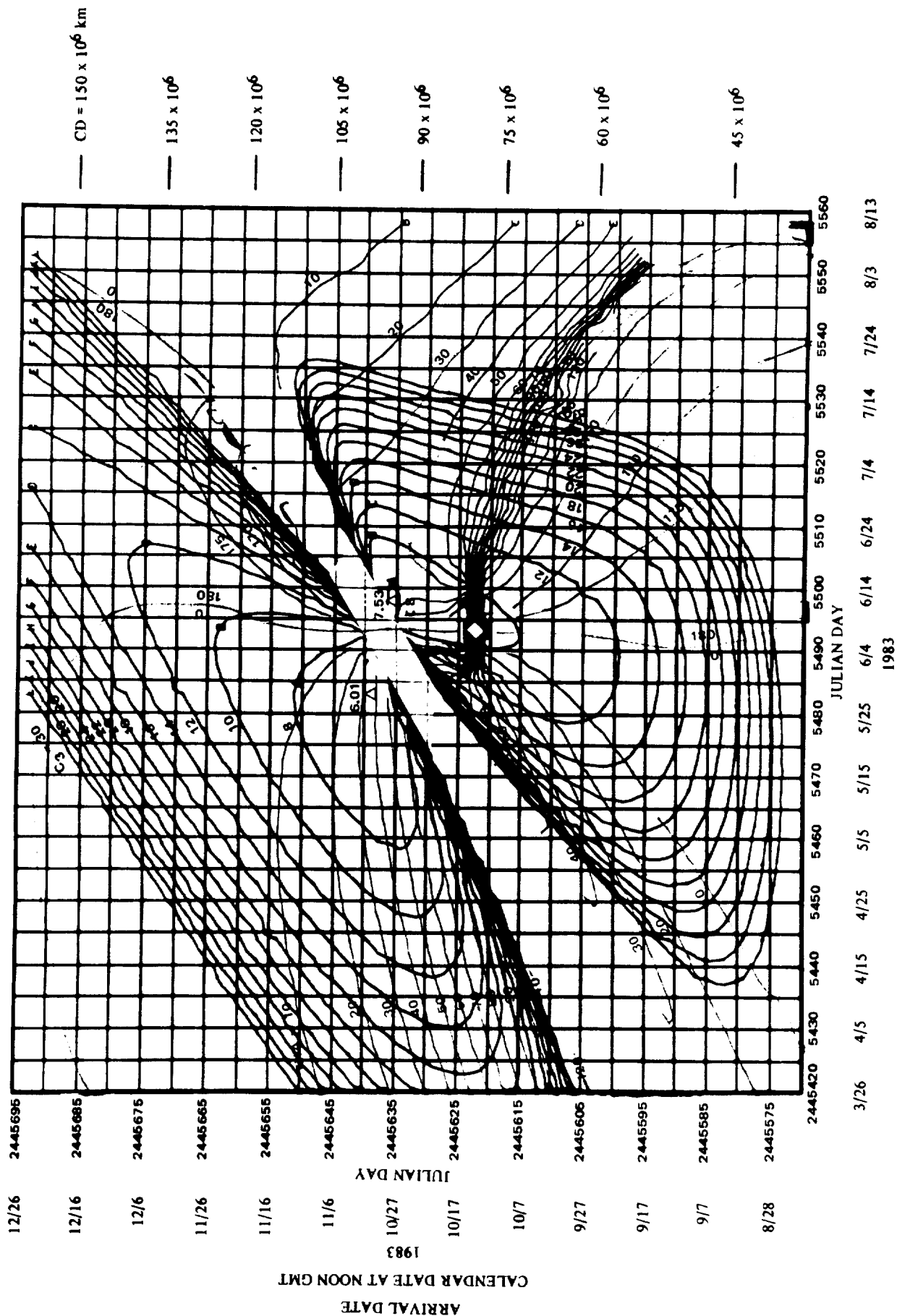


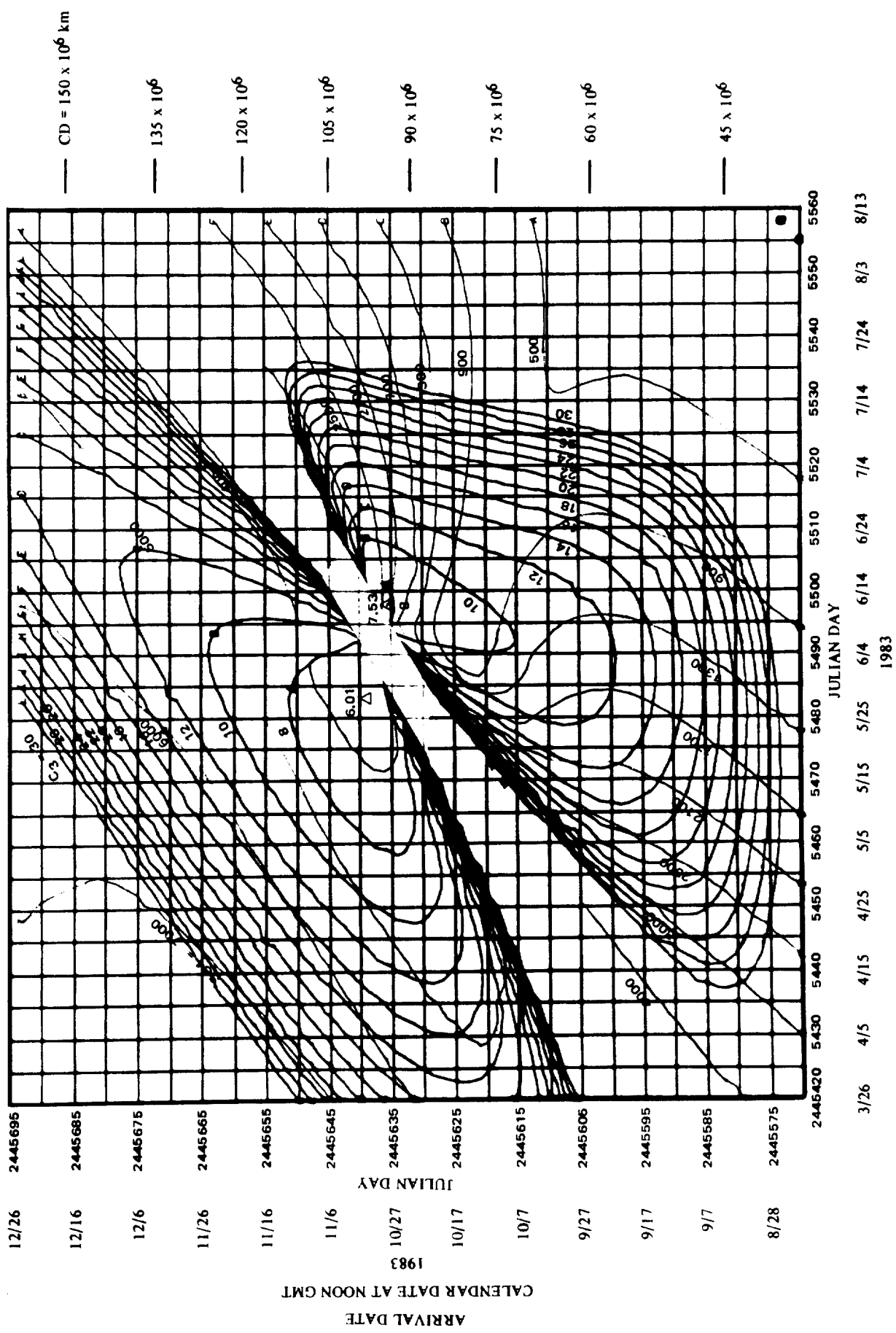


CALENDAR DATE AT NOON GMT

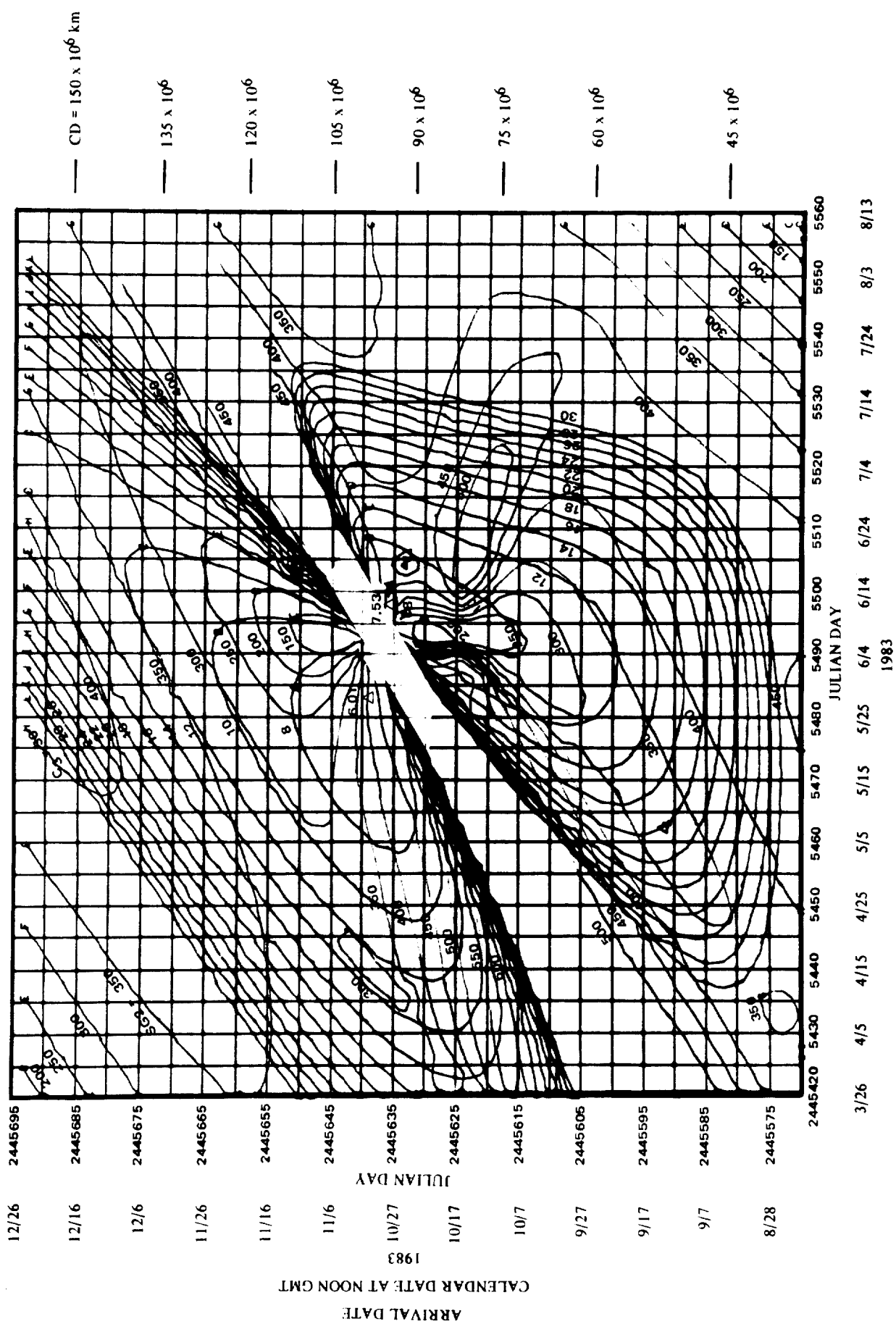
DEPARTURE DATE

CONTOURS OF C_3 AND ETE EARTH TO VENUS 1983

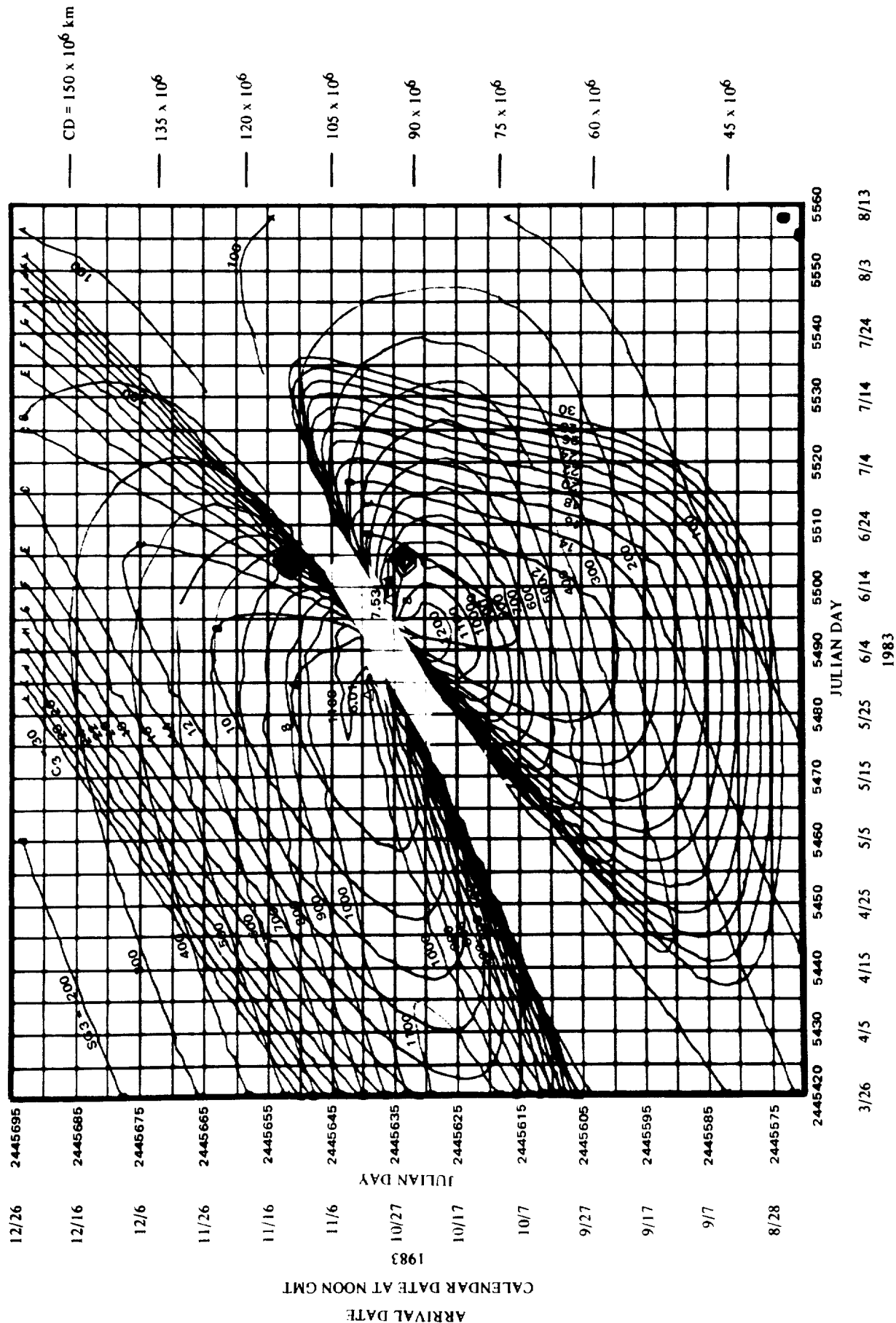




CONTOURS OF C_3 AND SG1 EARTH TO VENUS 1983



CONTOURS OF C_3 AND SG2 EARTH TO VENUS 1983

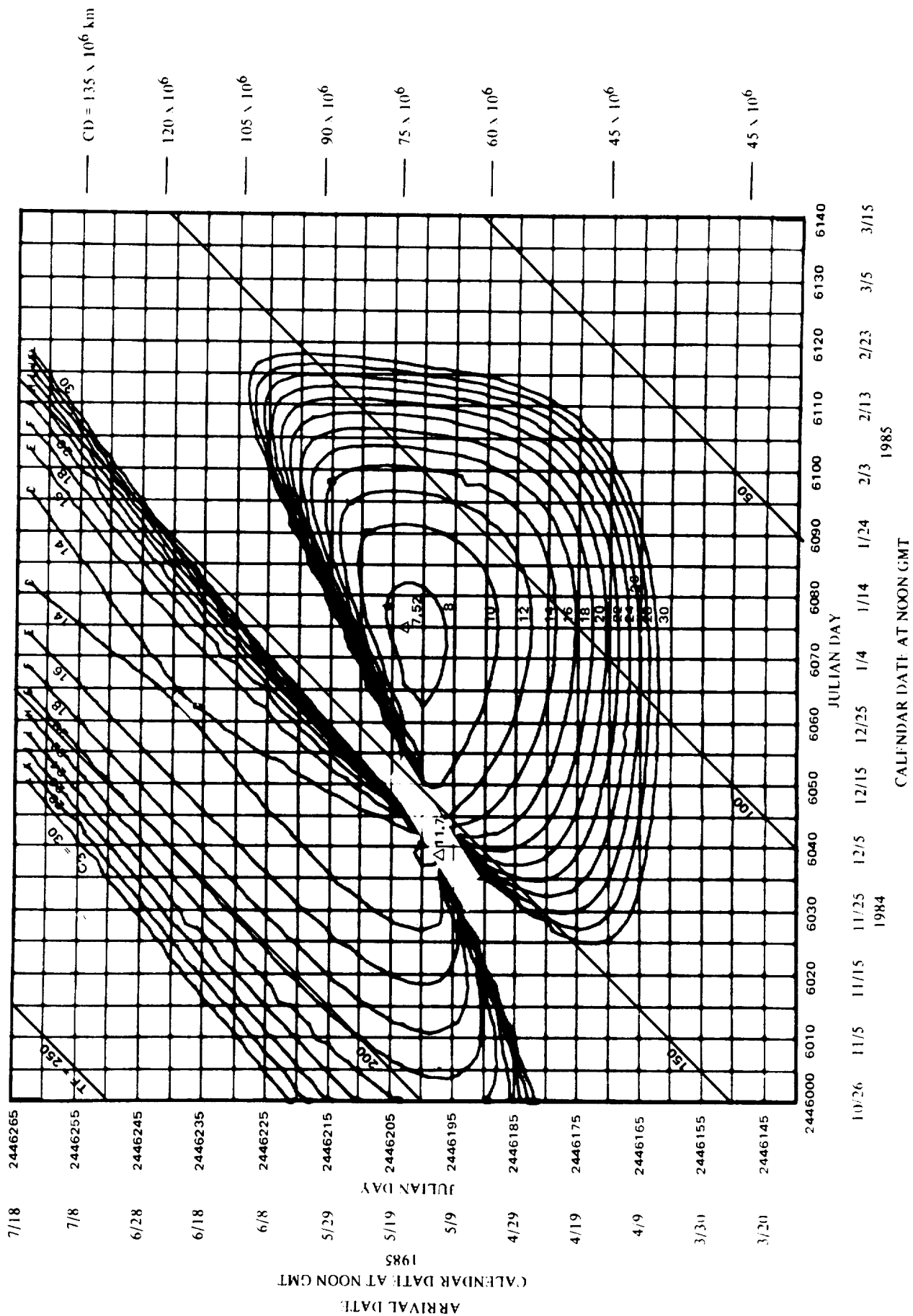


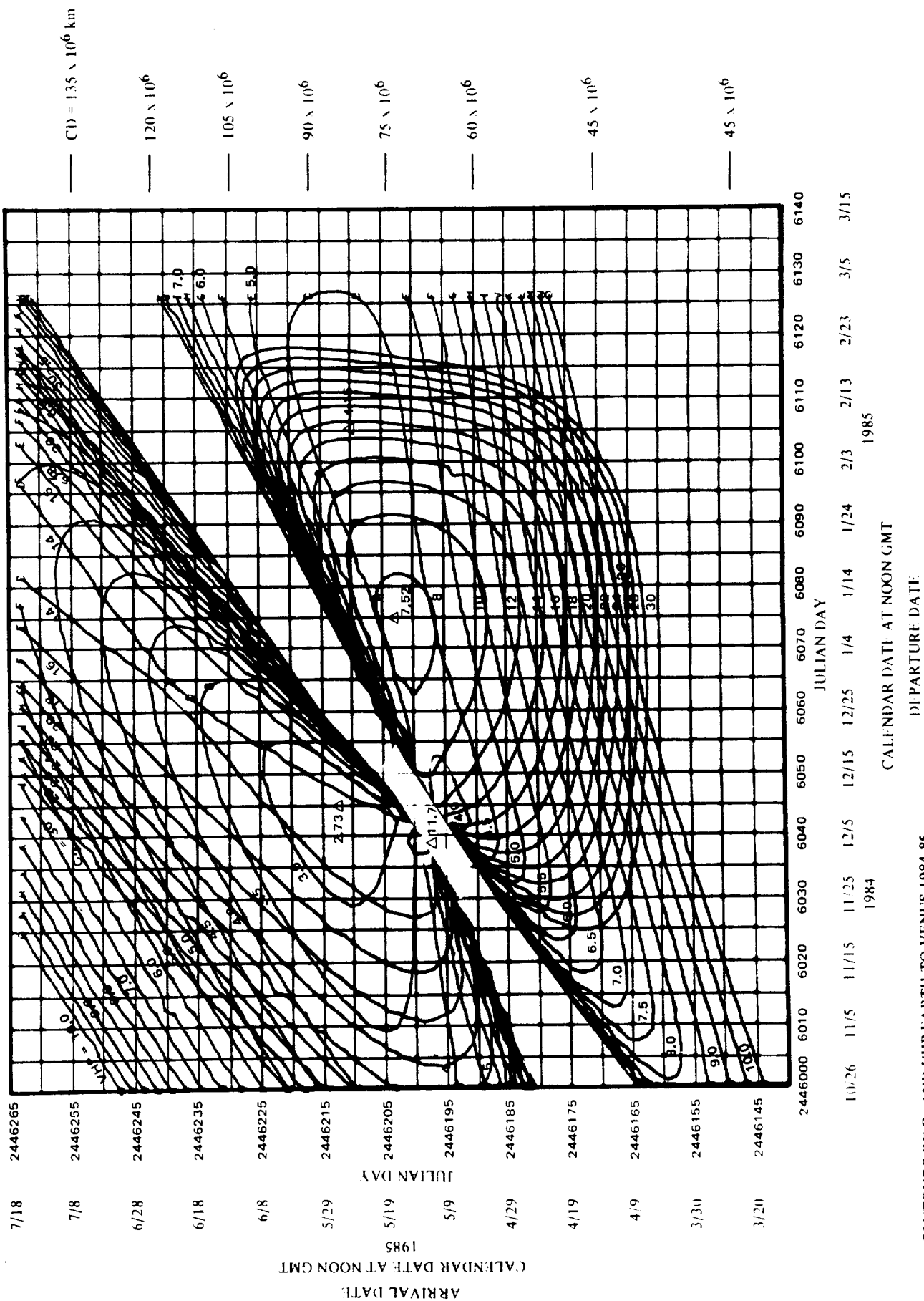
CONTOURS OF C_3 AND SG3 EARTH TO VENUS 1983

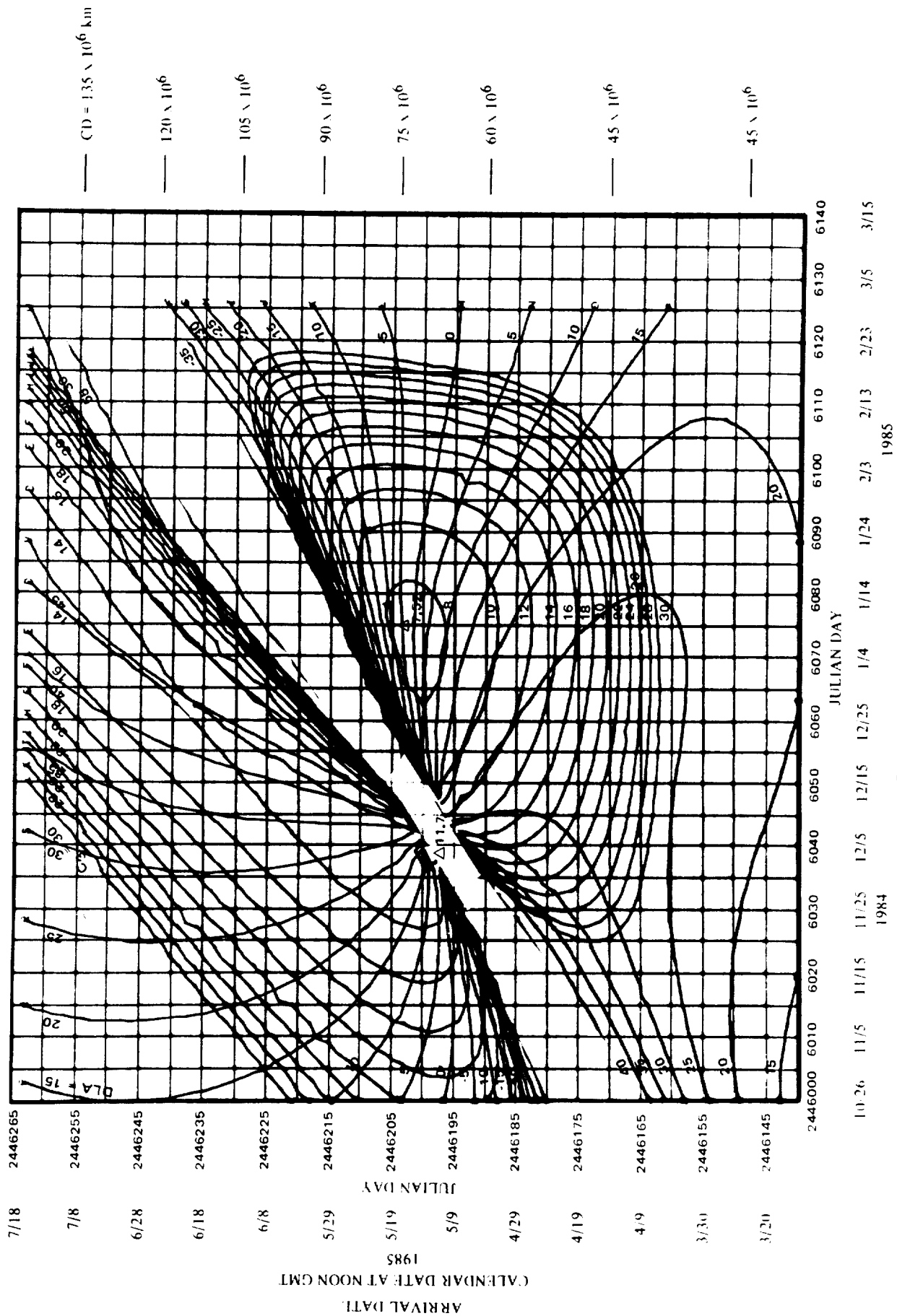
CALENDAR DATE AT NOON GMT

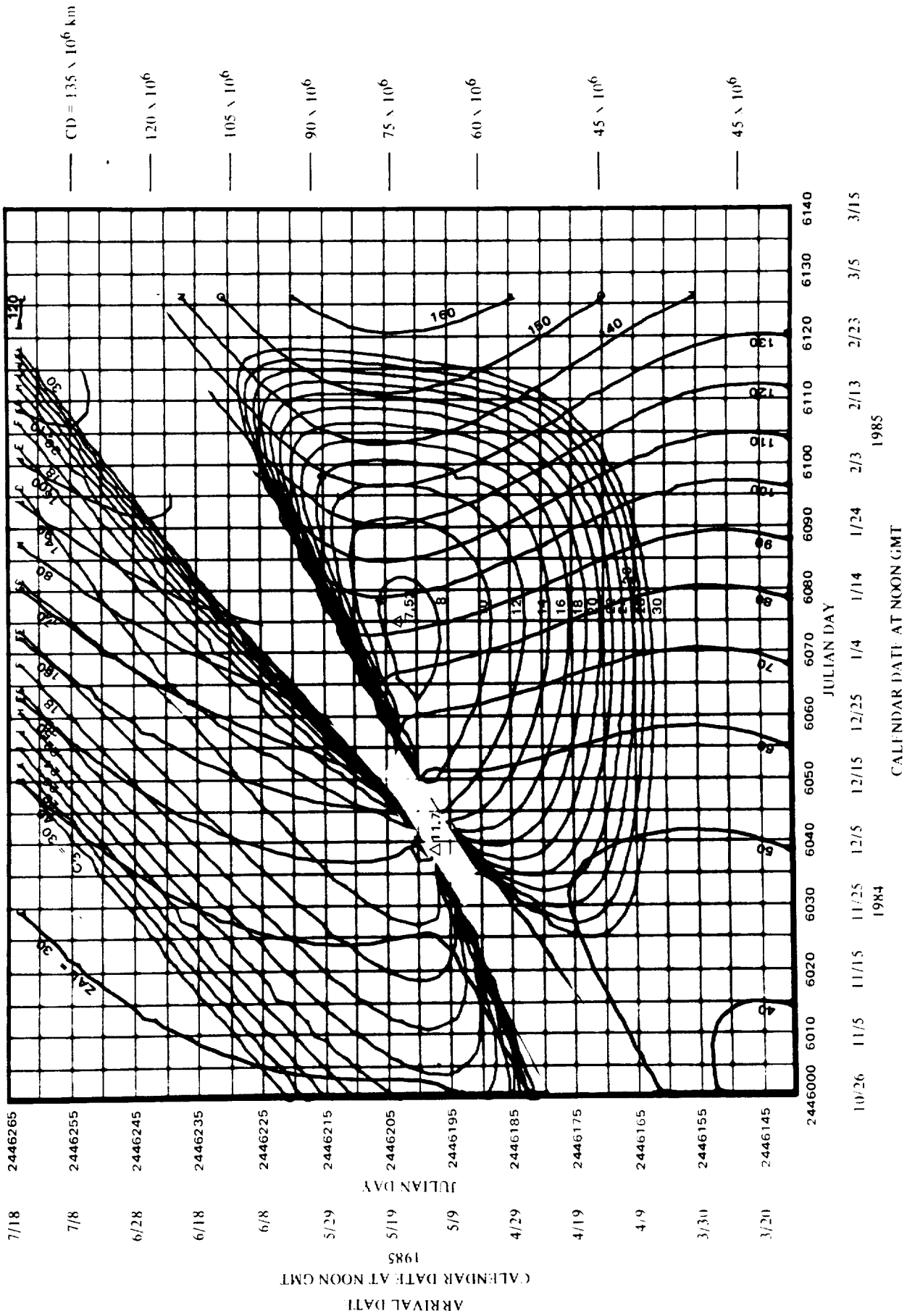
DEPARTURE DATE

1983

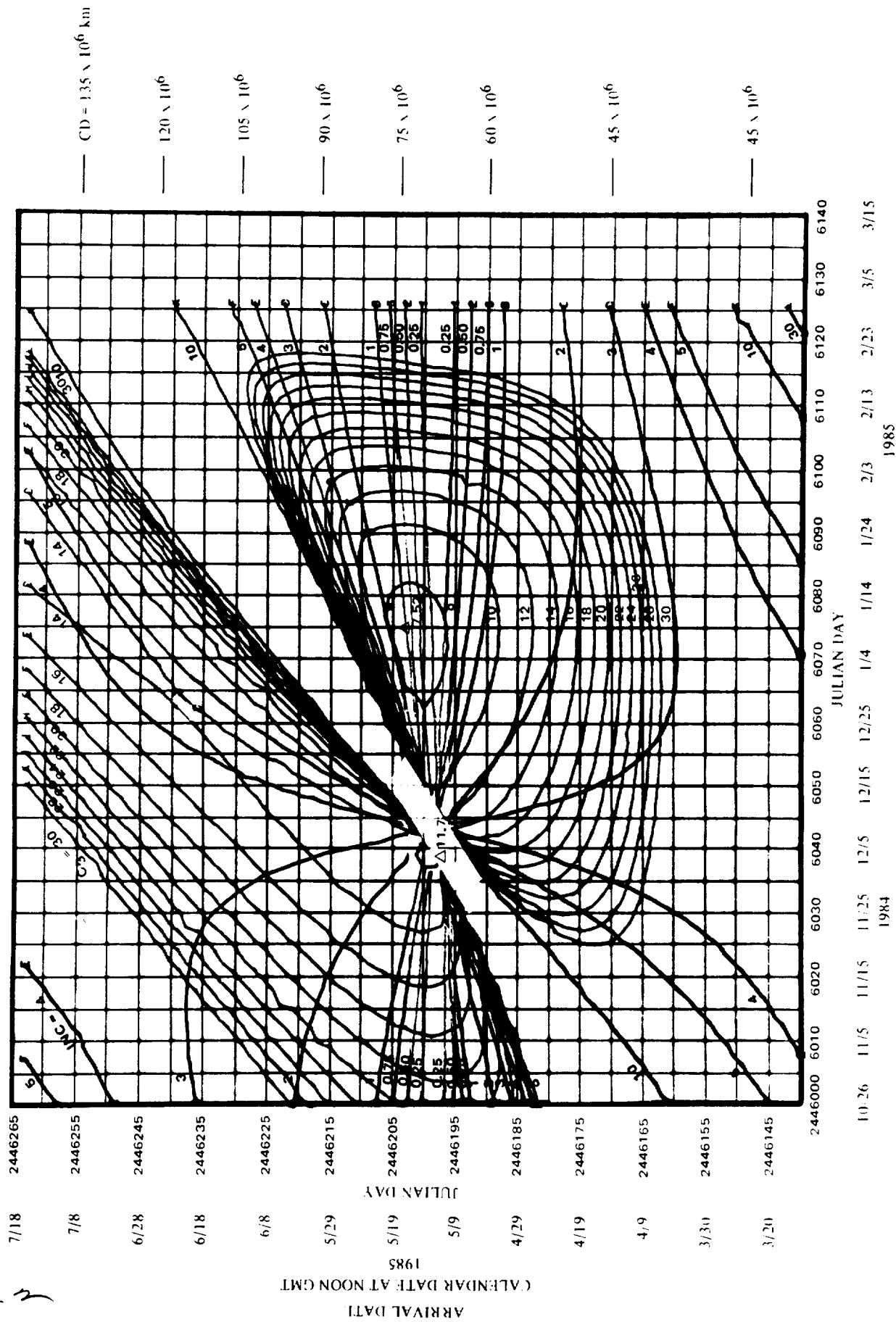


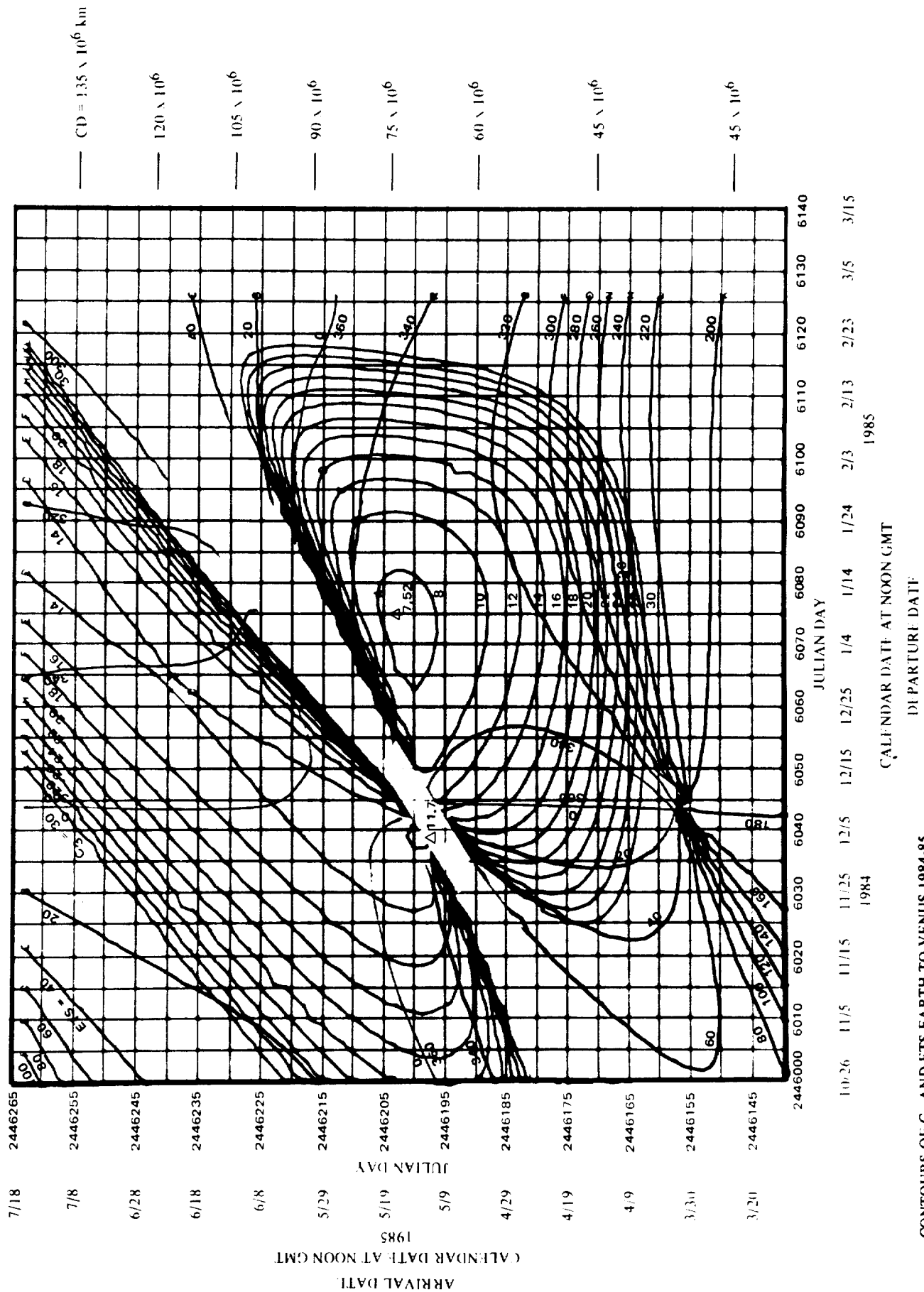




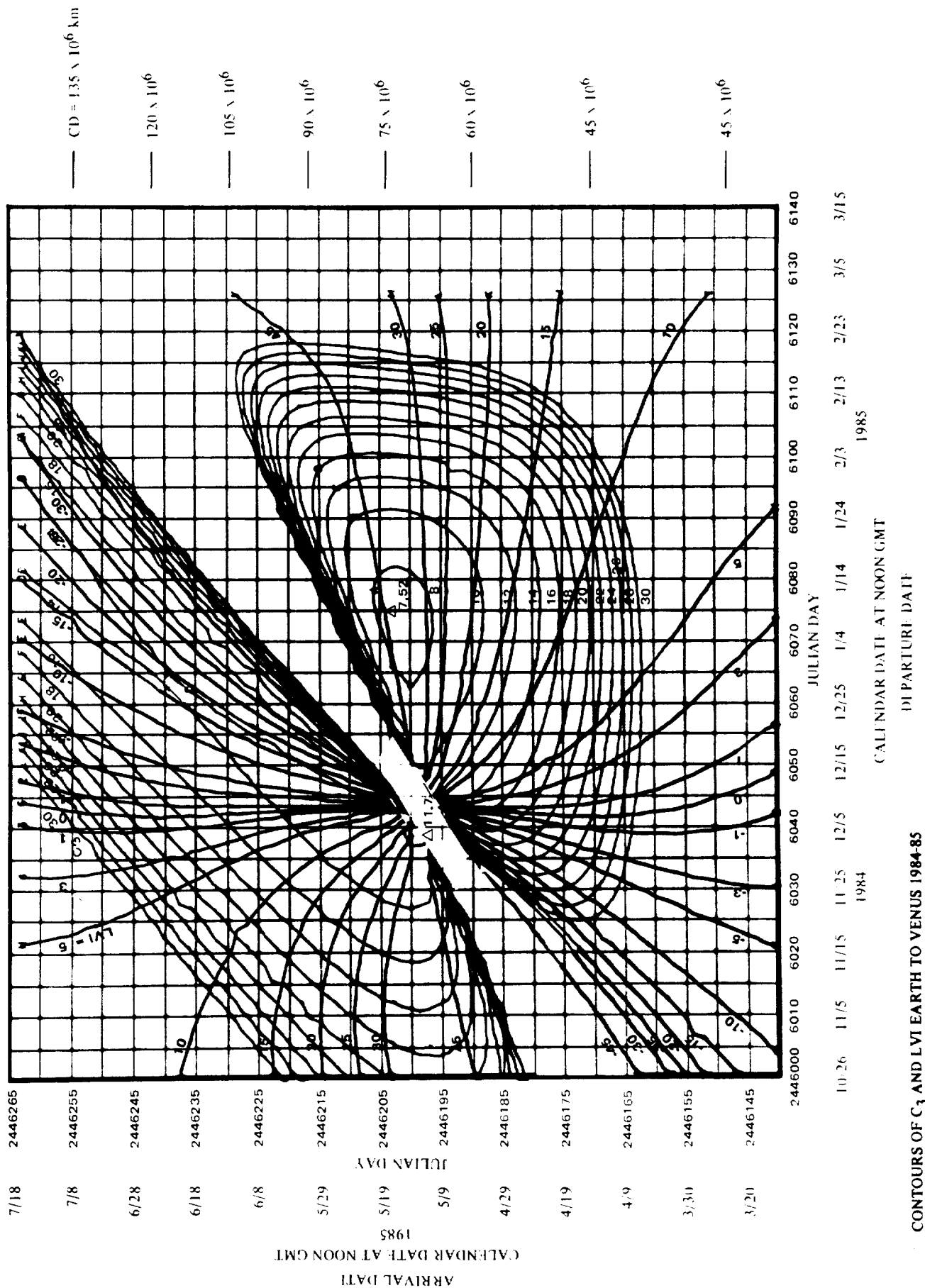


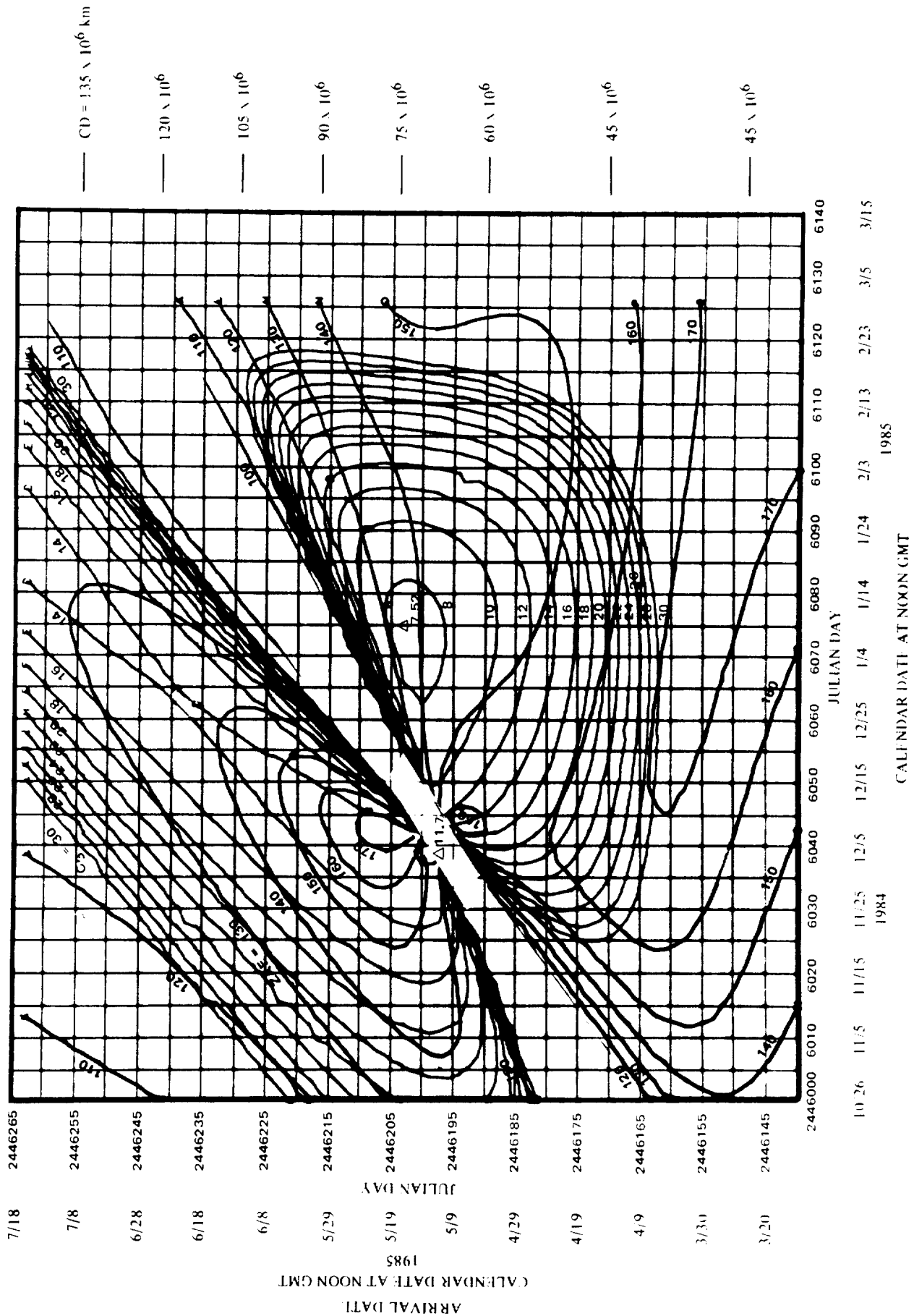
7-2



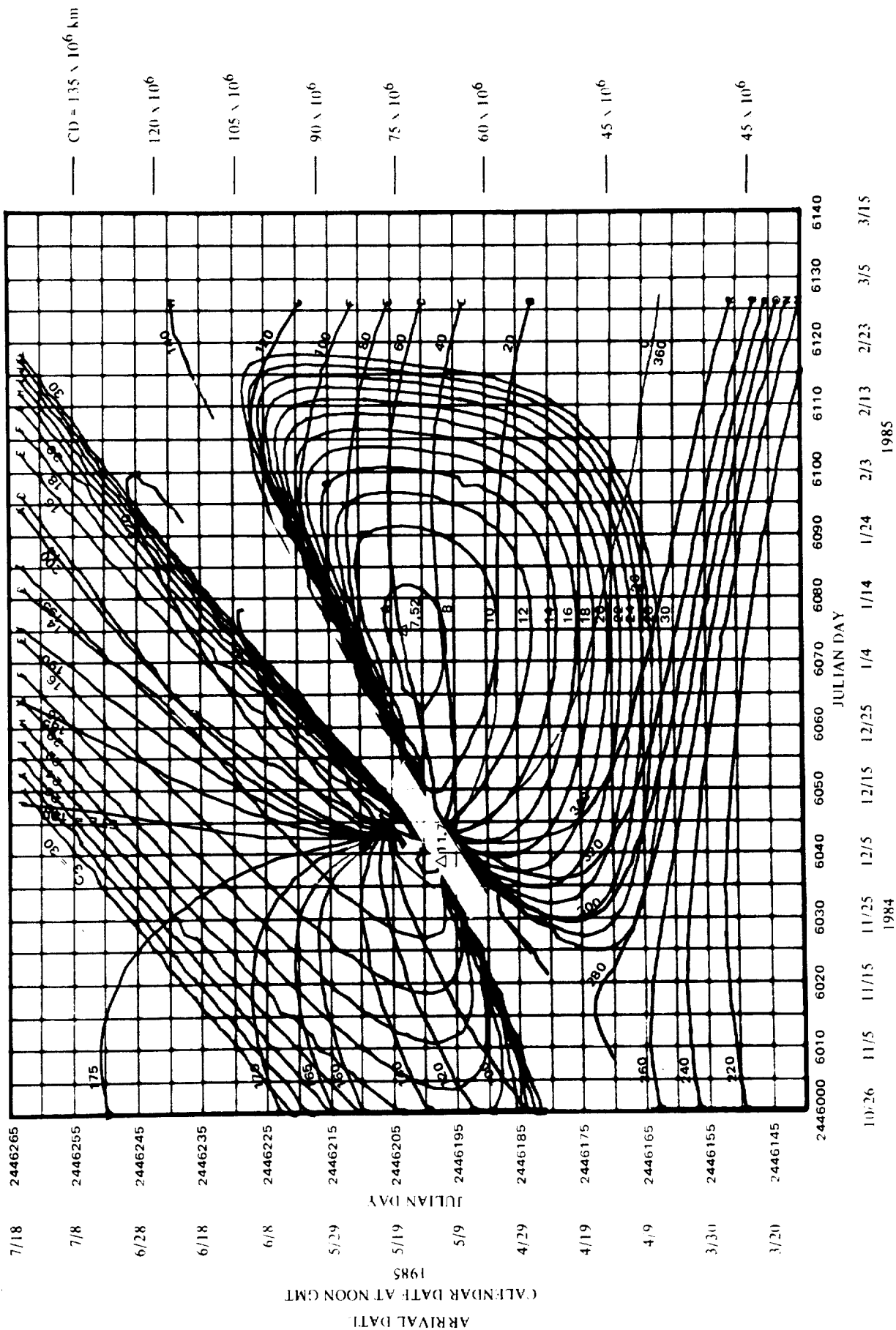


CONTOURS OF C_3 AND ETS EARTH TO VENUS 1984-85



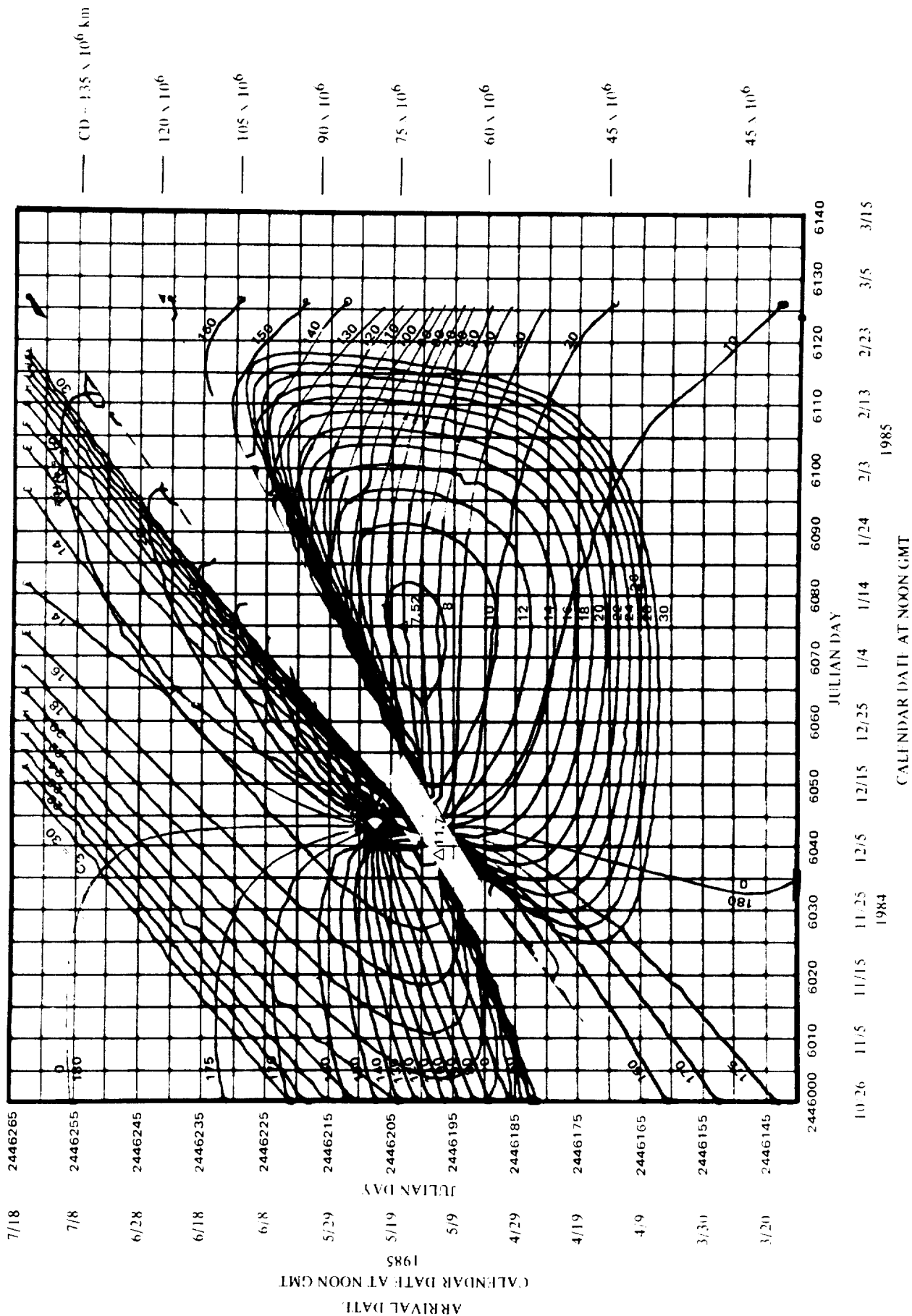


CONTOURS OF C_3 AND ZAE EARTH TO VENUS 1984-85

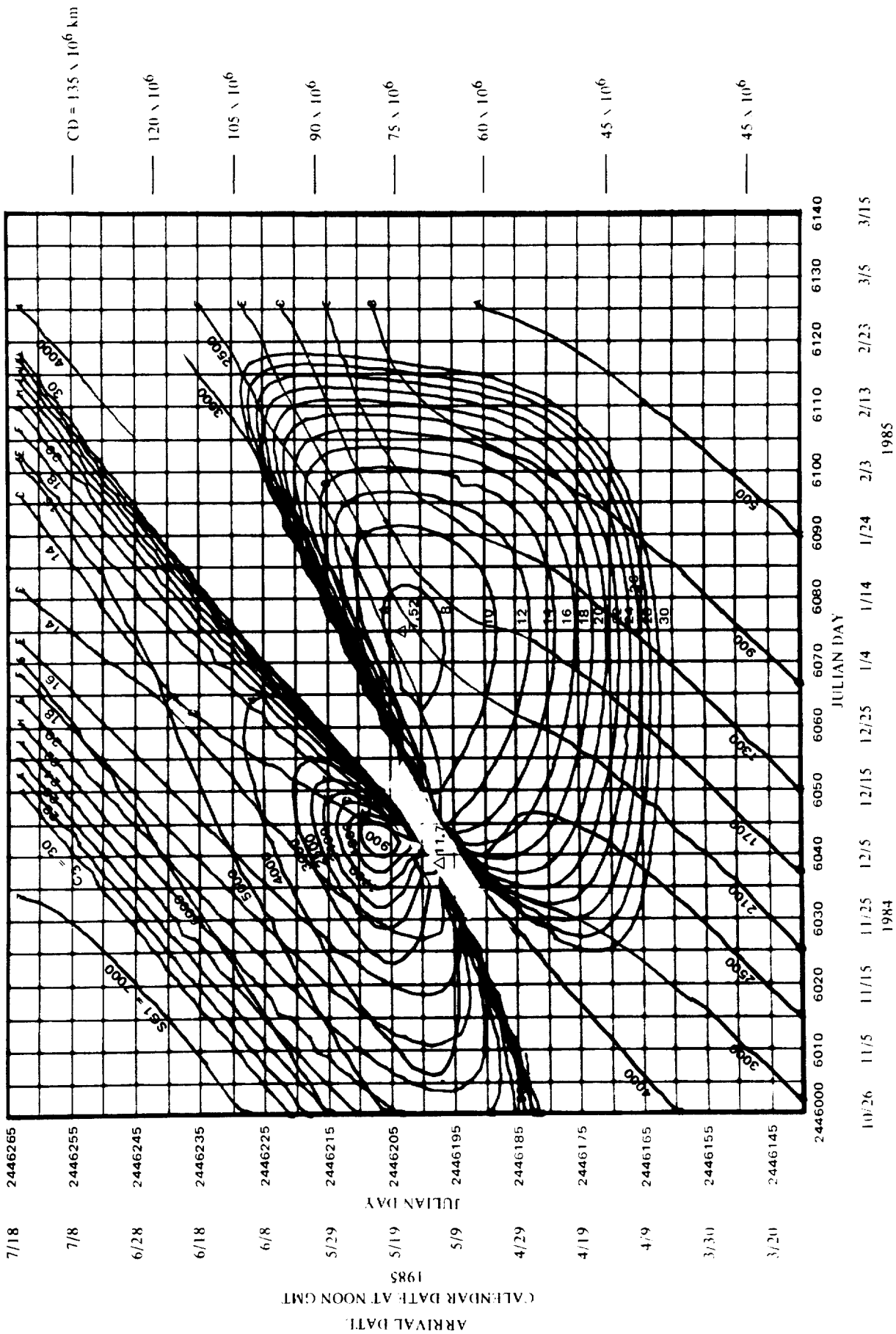


CALENDAR DATE AT NOON GMT
DEPARTURE DATE

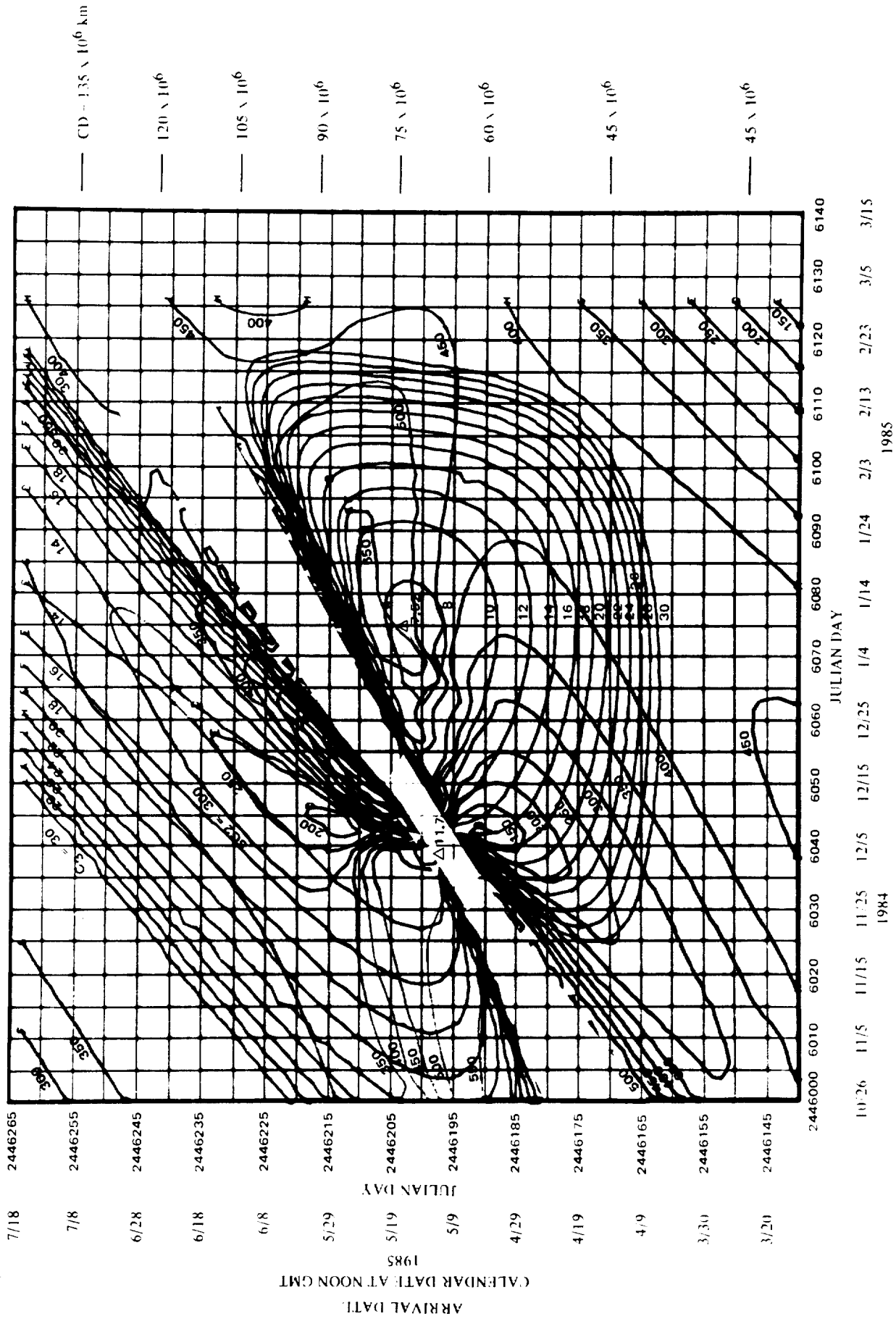
CONTOURS OF C₃ AND ETE EARTH TO VENUS 1984-85



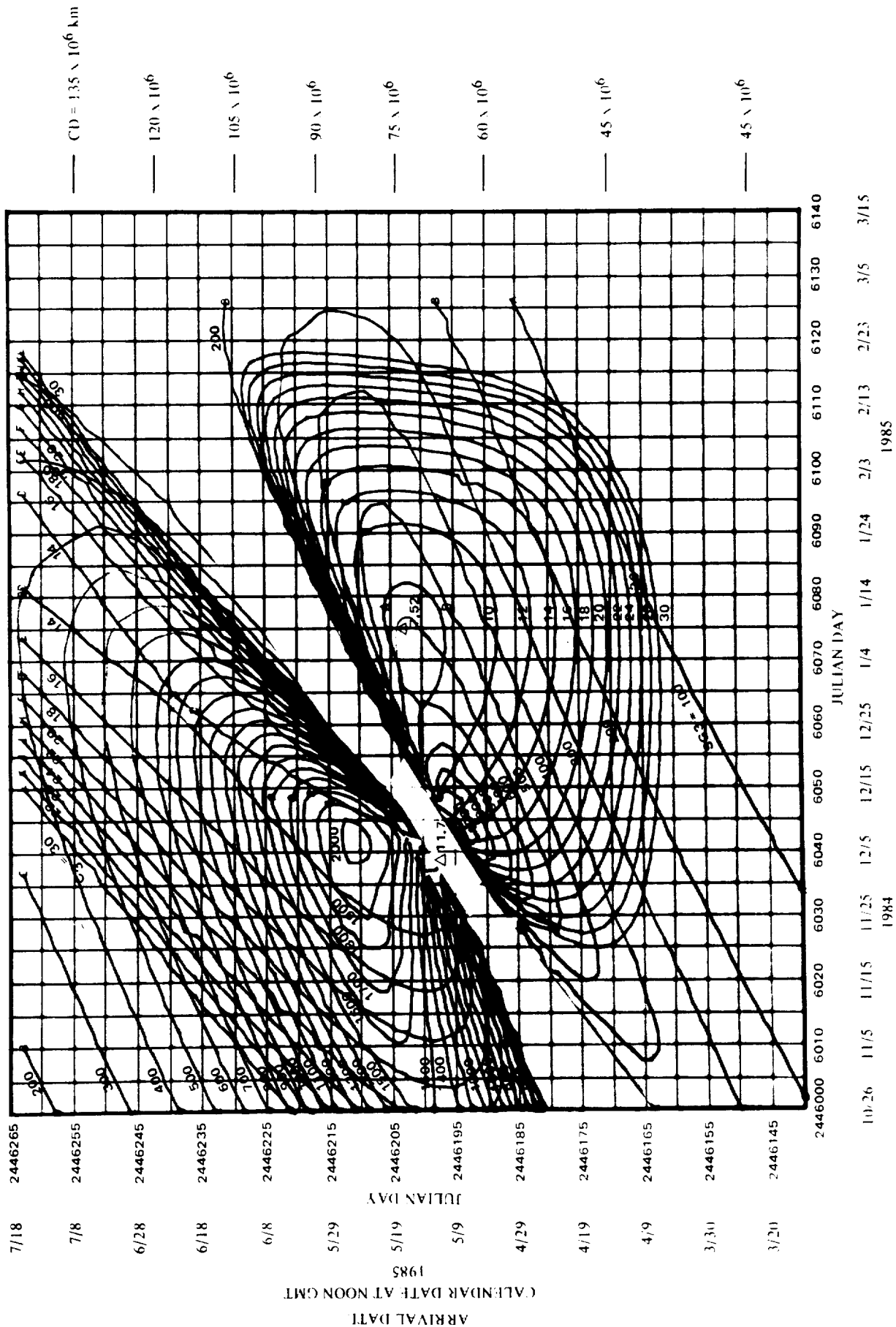
CONTOURS OF C_3 AND THA EARTH TO VENUS 1984-85



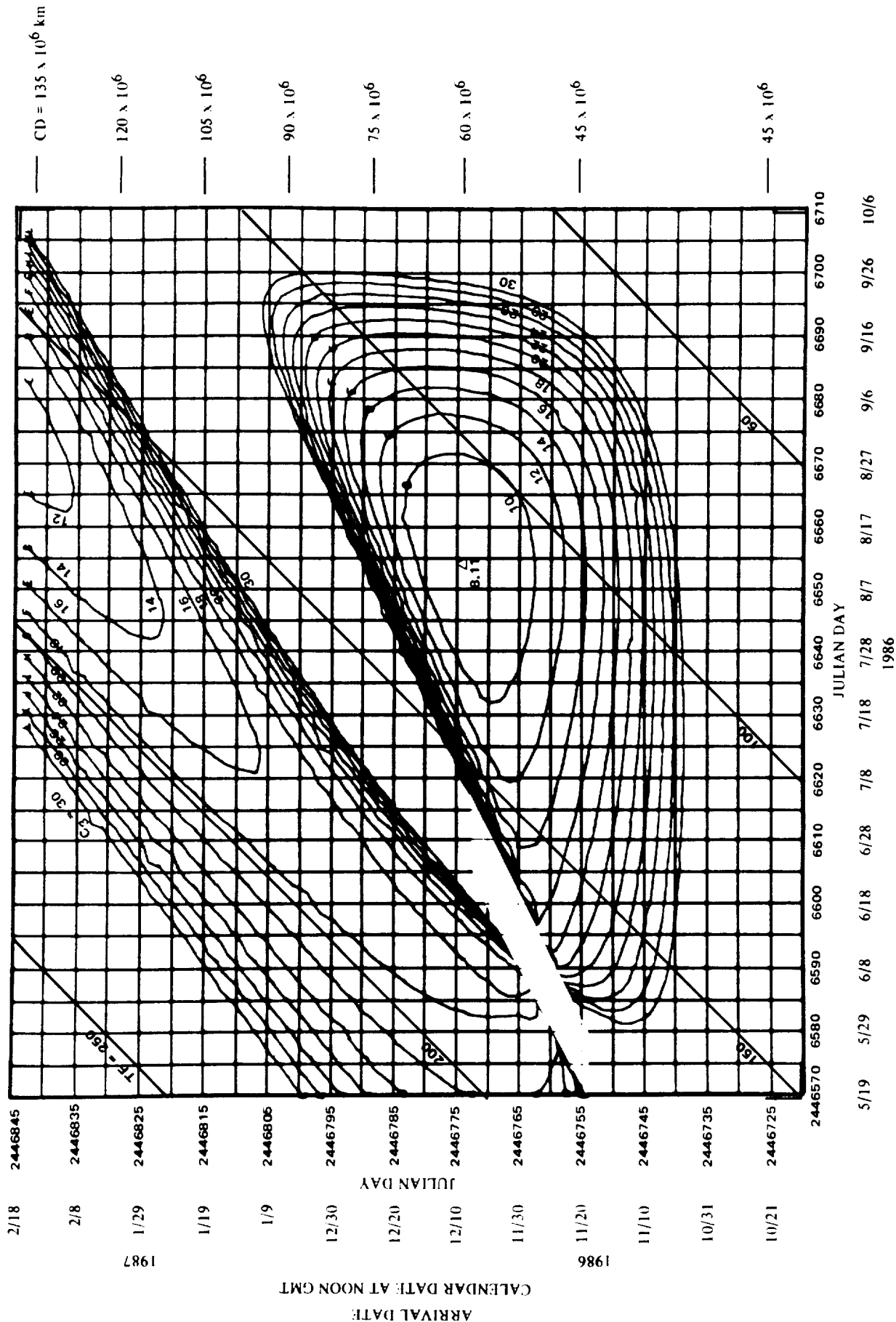
CONTOURS OF C_3 AND SGI EARTH TO VENUS 1984-85



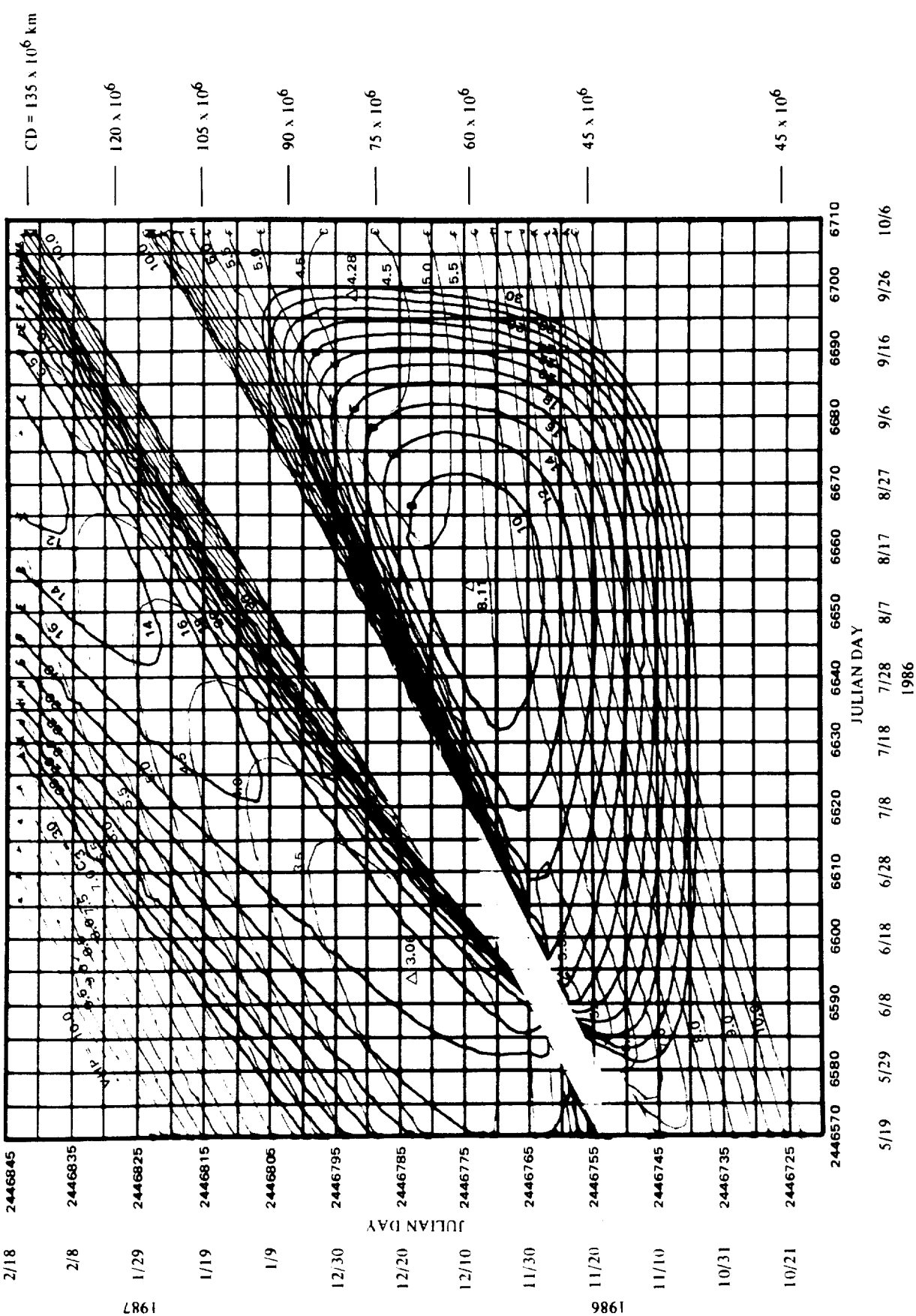
CONTOURS OF C_3 AND SG2 EARTH TO VENUS 1984-85



CONTOURS OF C_1 AND SG3 EARTH TO VENUS 1984 85



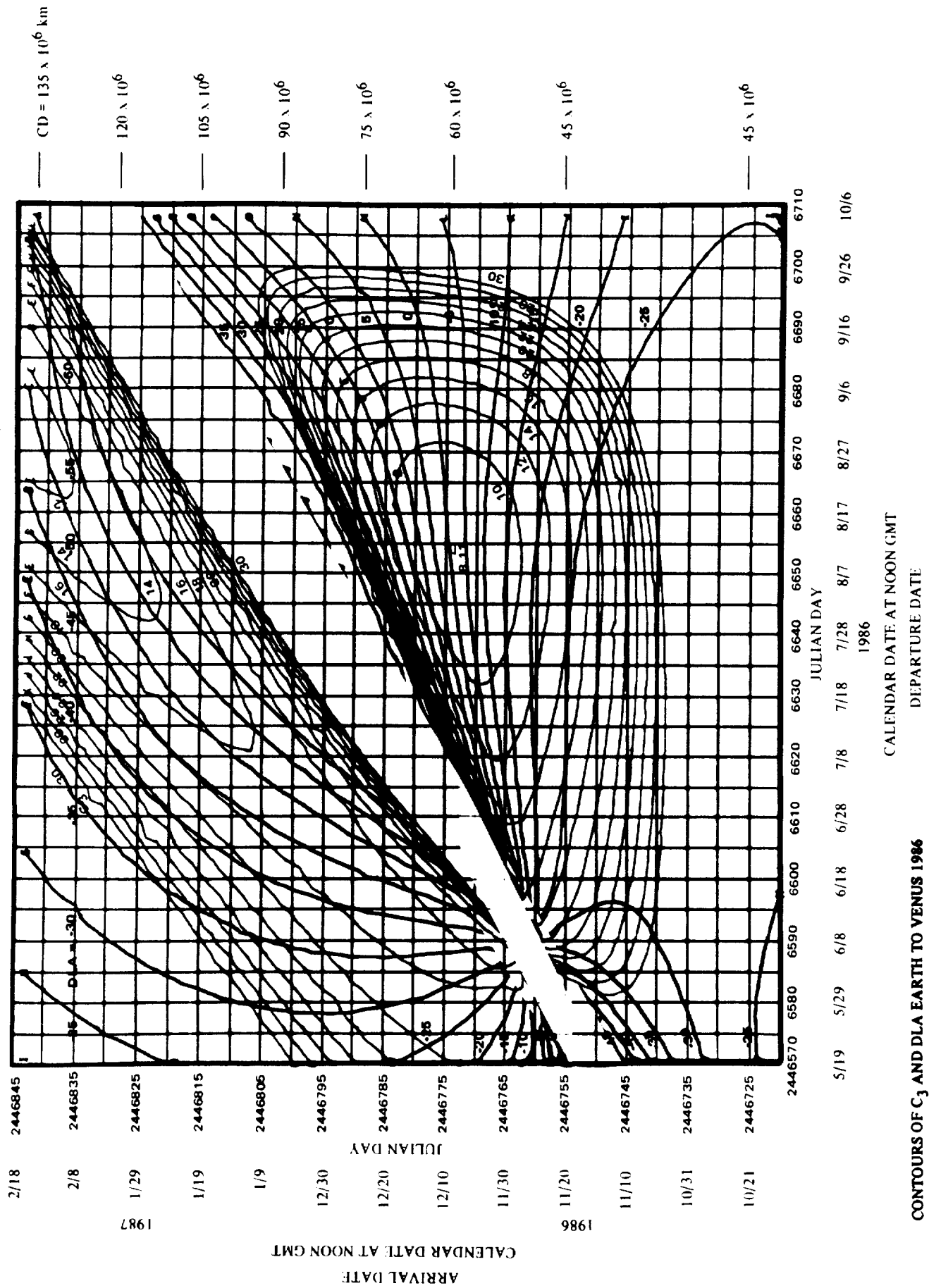
CONTOURS OF C_3 AND FLIGHT TIMES EARTH TO VENUS 1986

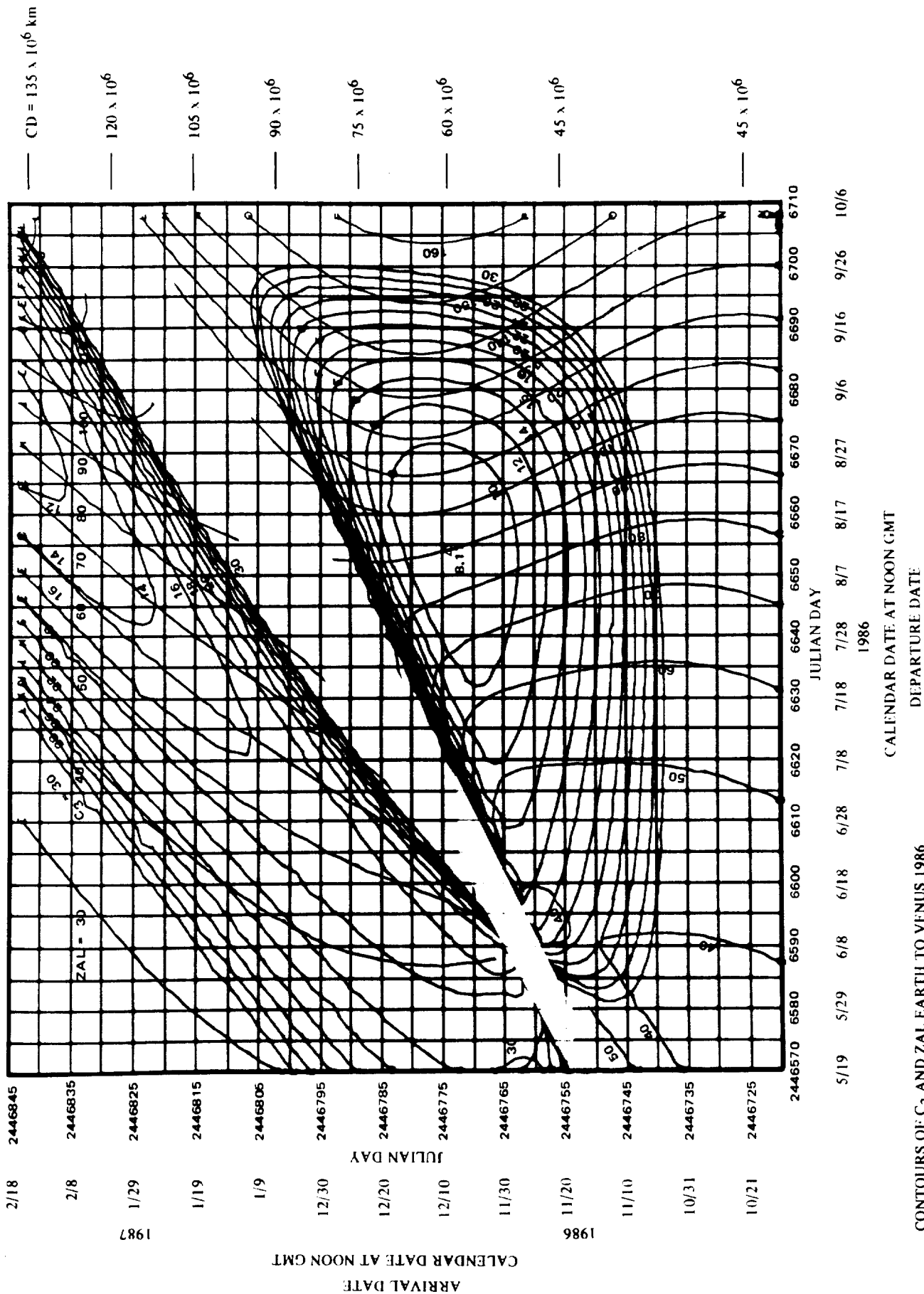


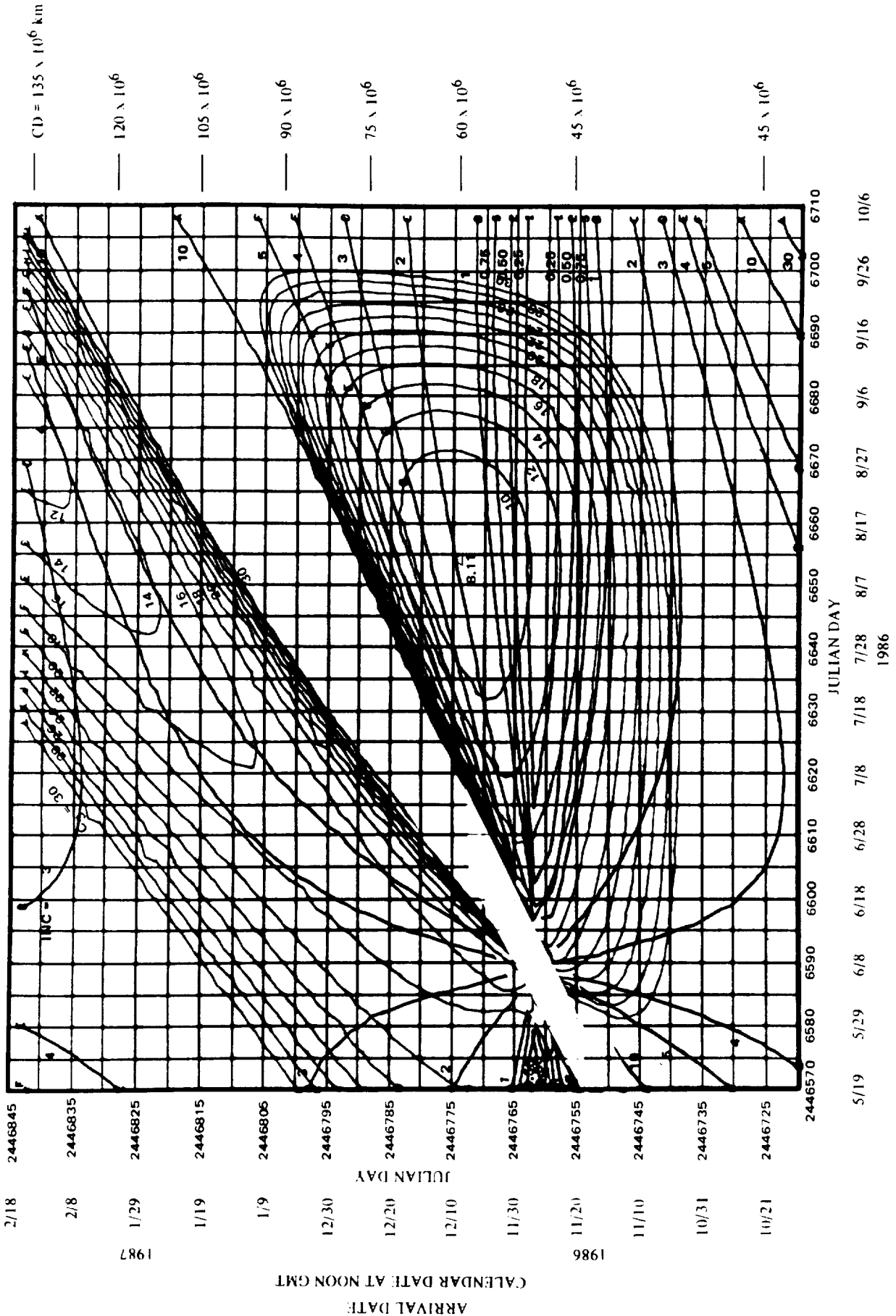
ARRIVAL DATE AT NOON GMT

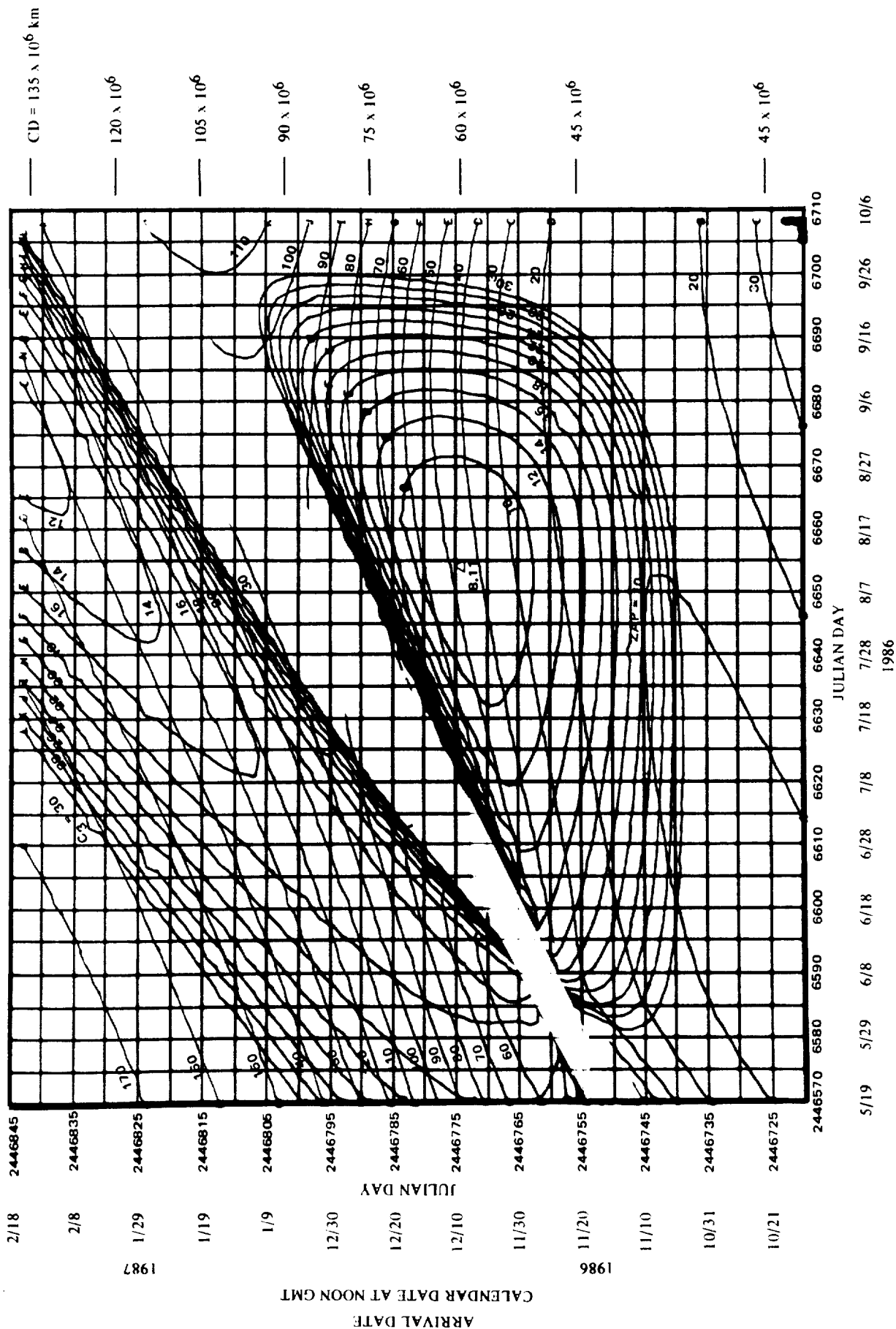
DEPARTURE DATE

CONTOURS OF C_3 AND VIPI EARTH TO VENUS 1986

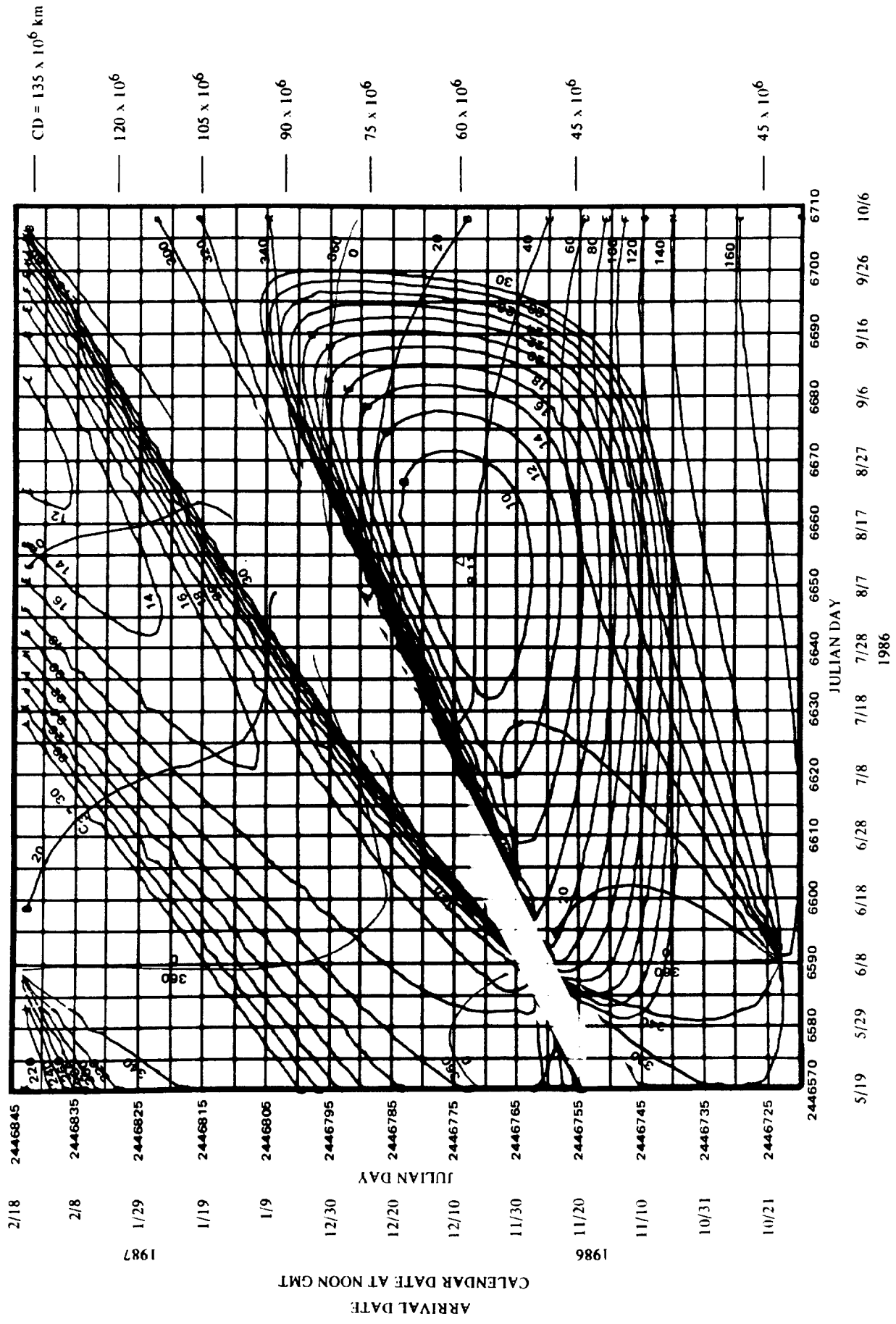






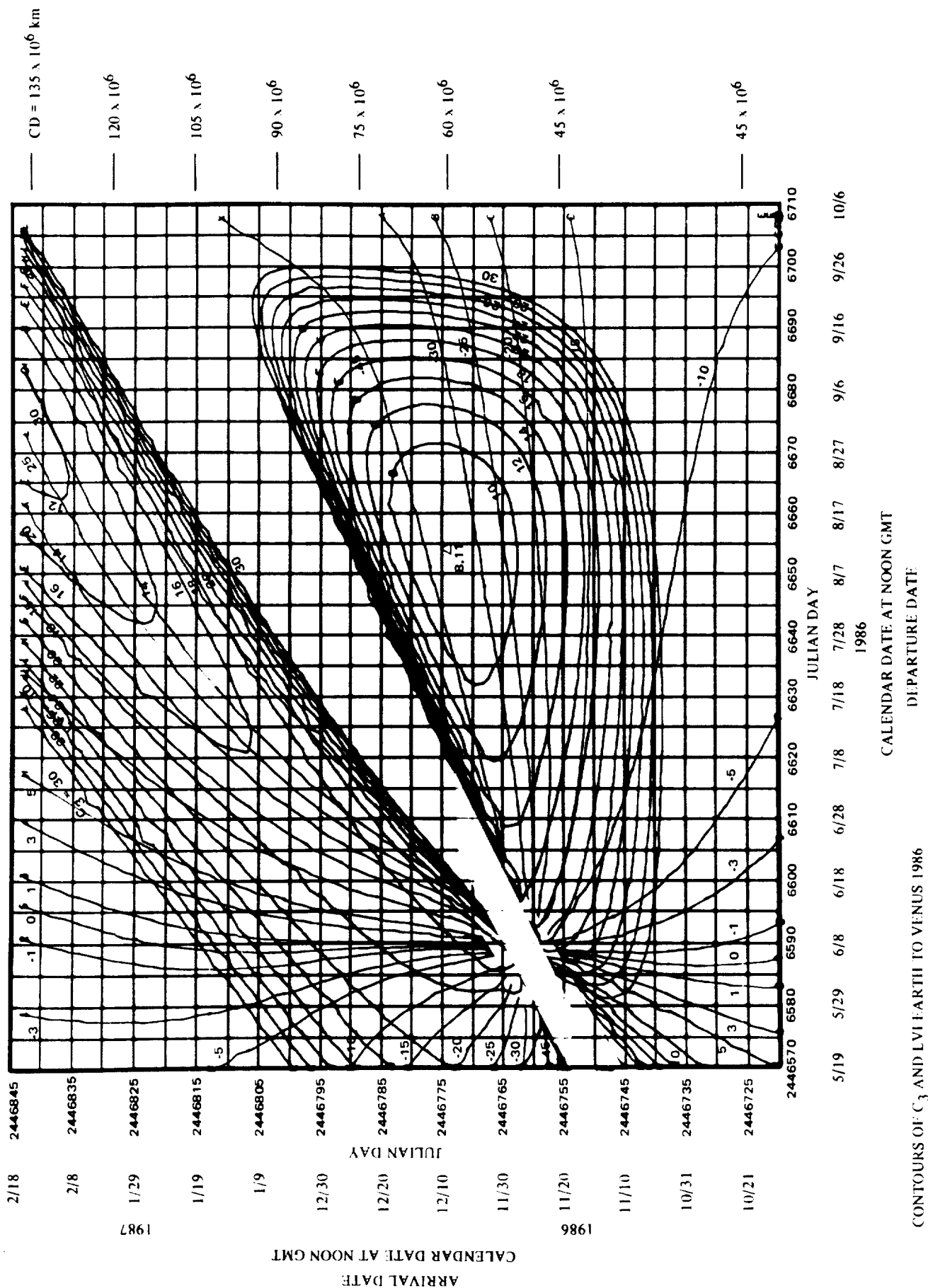


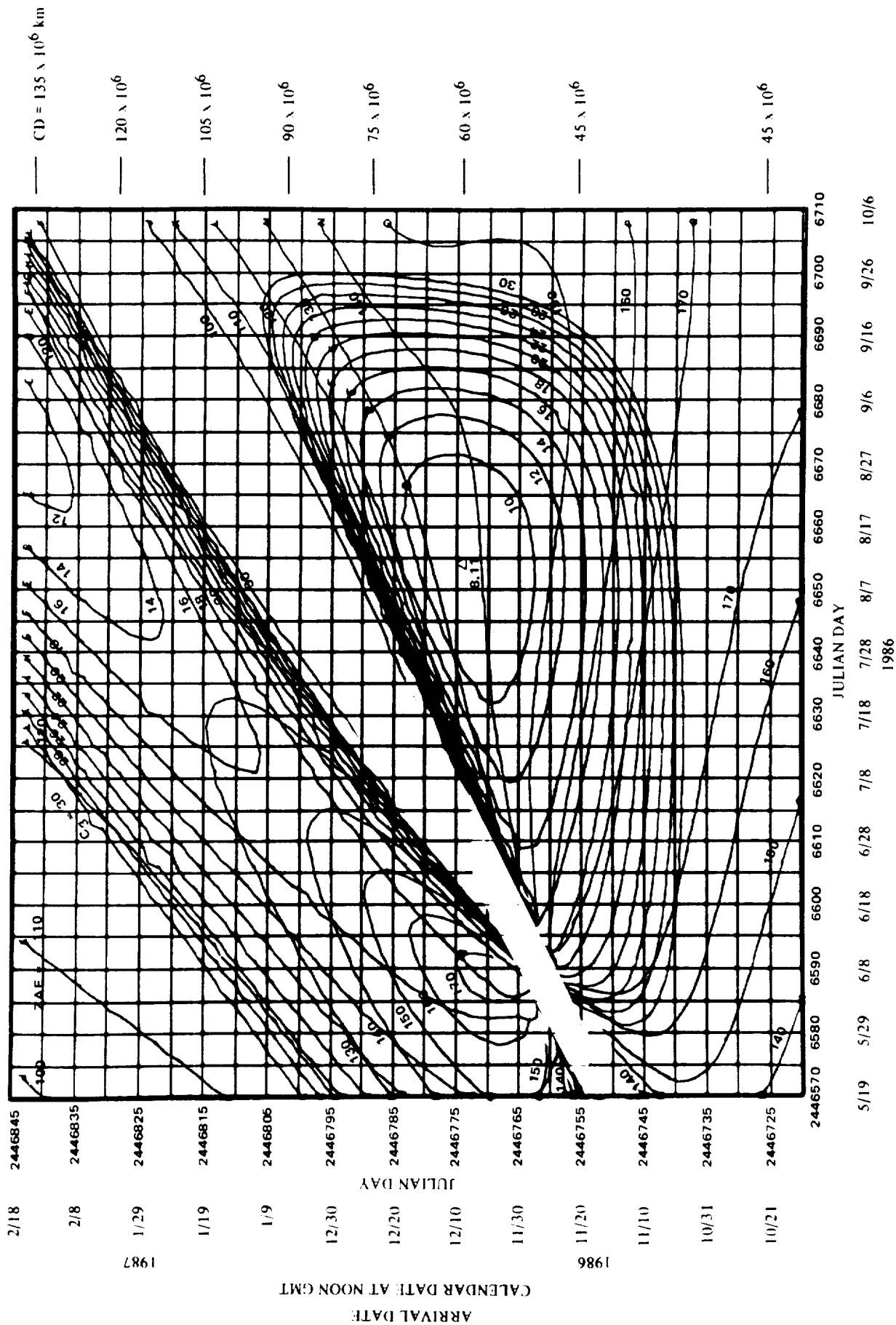
CONTOURS OF C_3 AND ZAP EARTH TO VENUS 1986

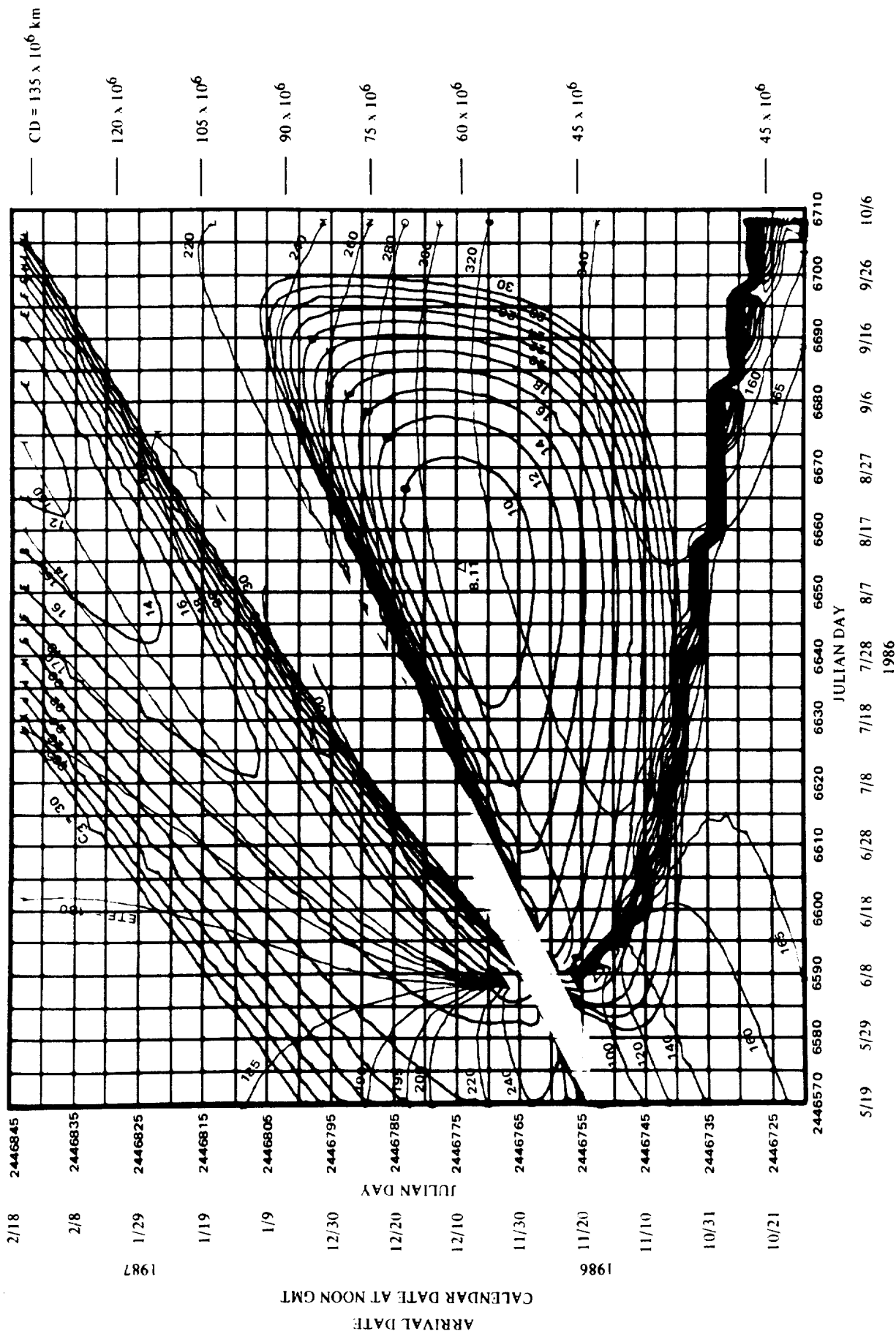


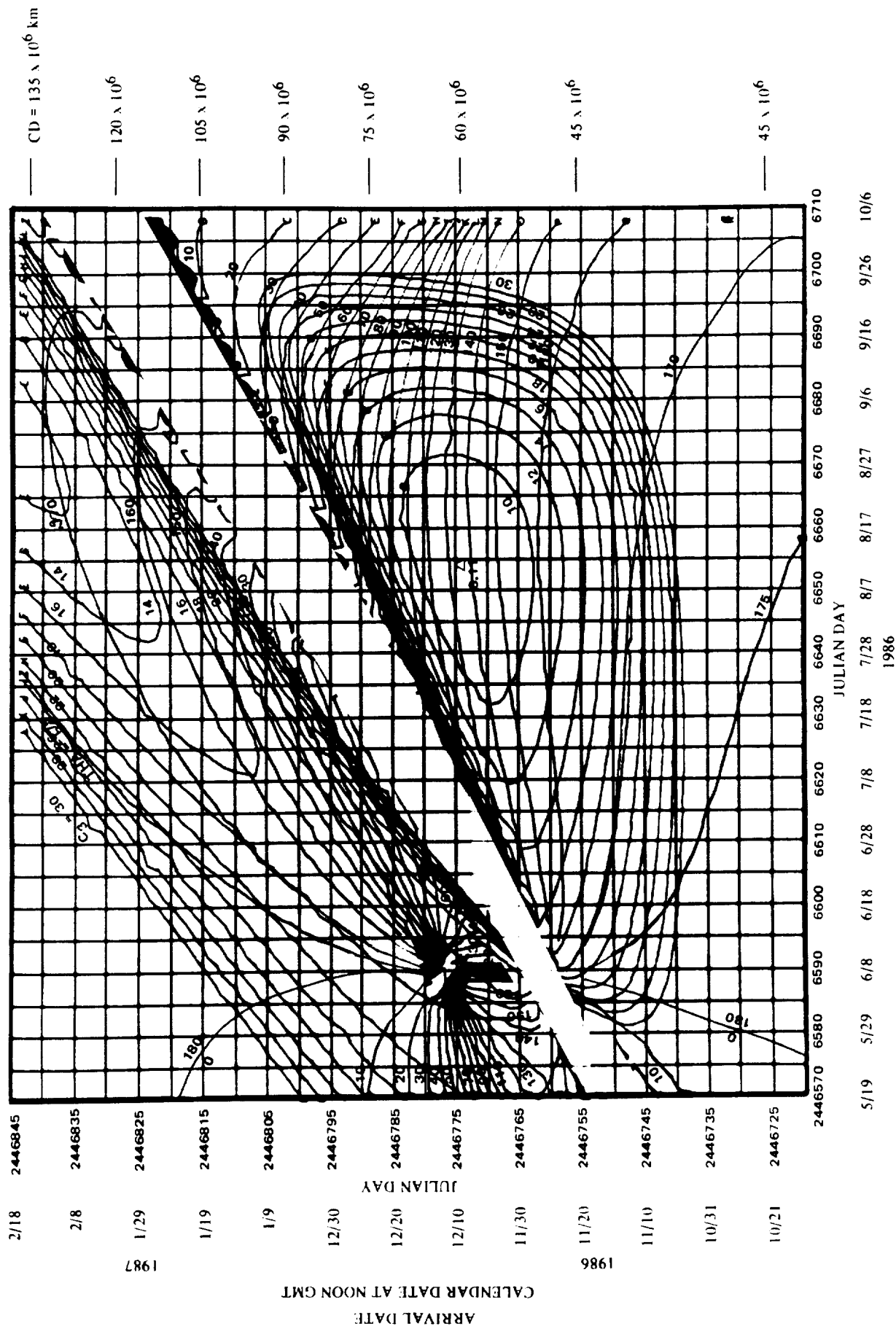
CALENDAR DATE AT NOON GMT
 DEPARTURE DATE

CONTOURS OF C_3 AND ETS EARTH TO VENUS 1986

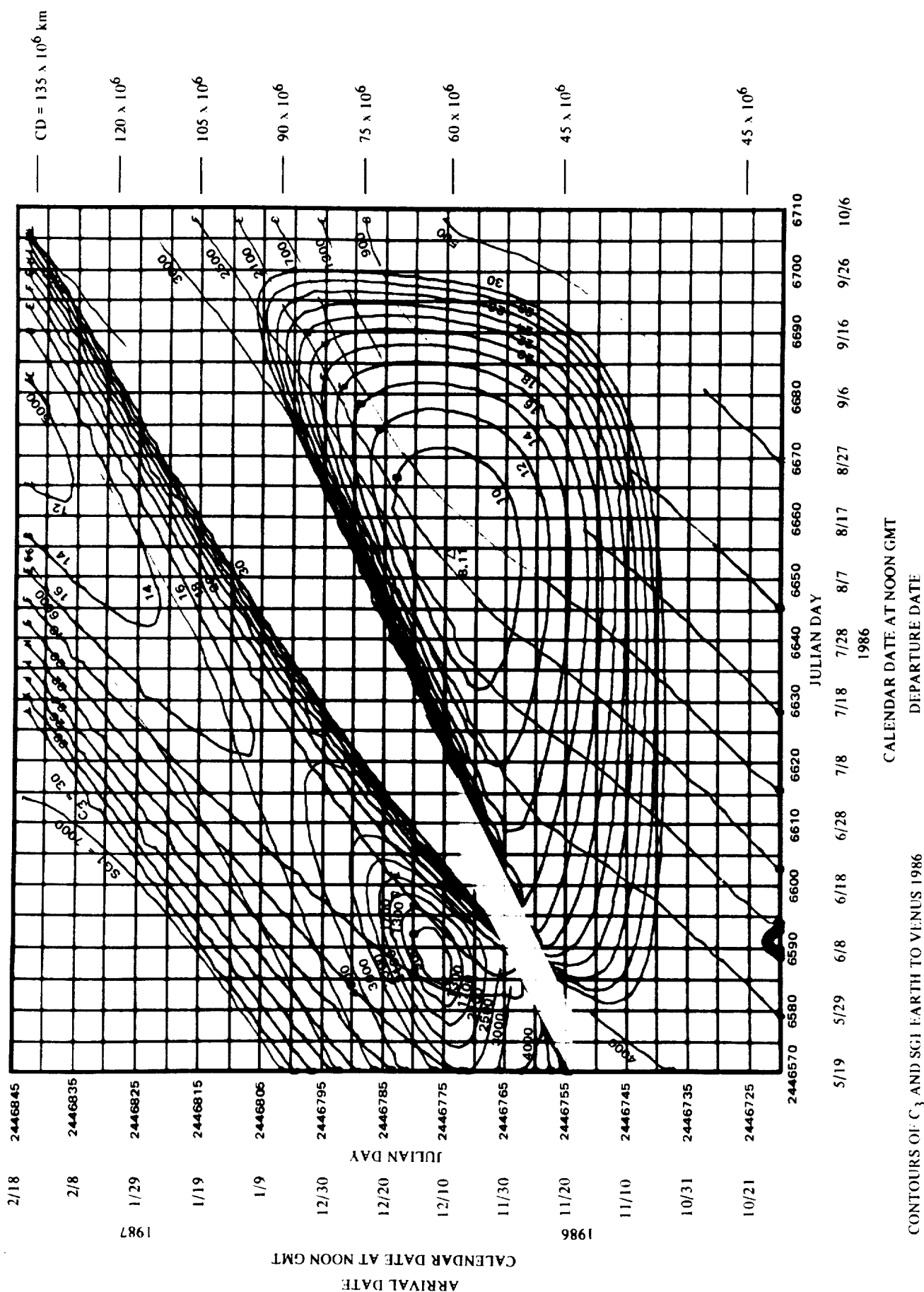


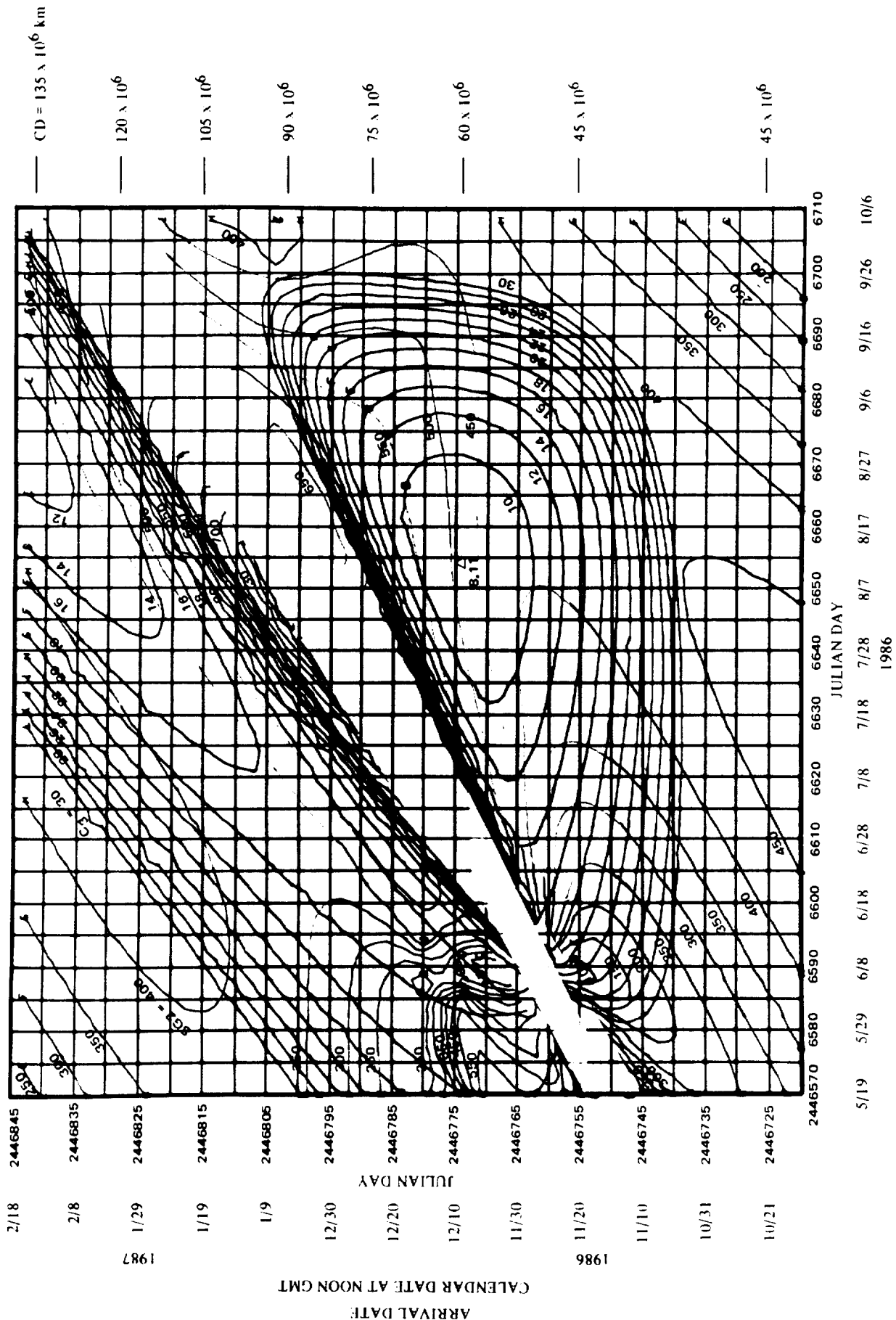


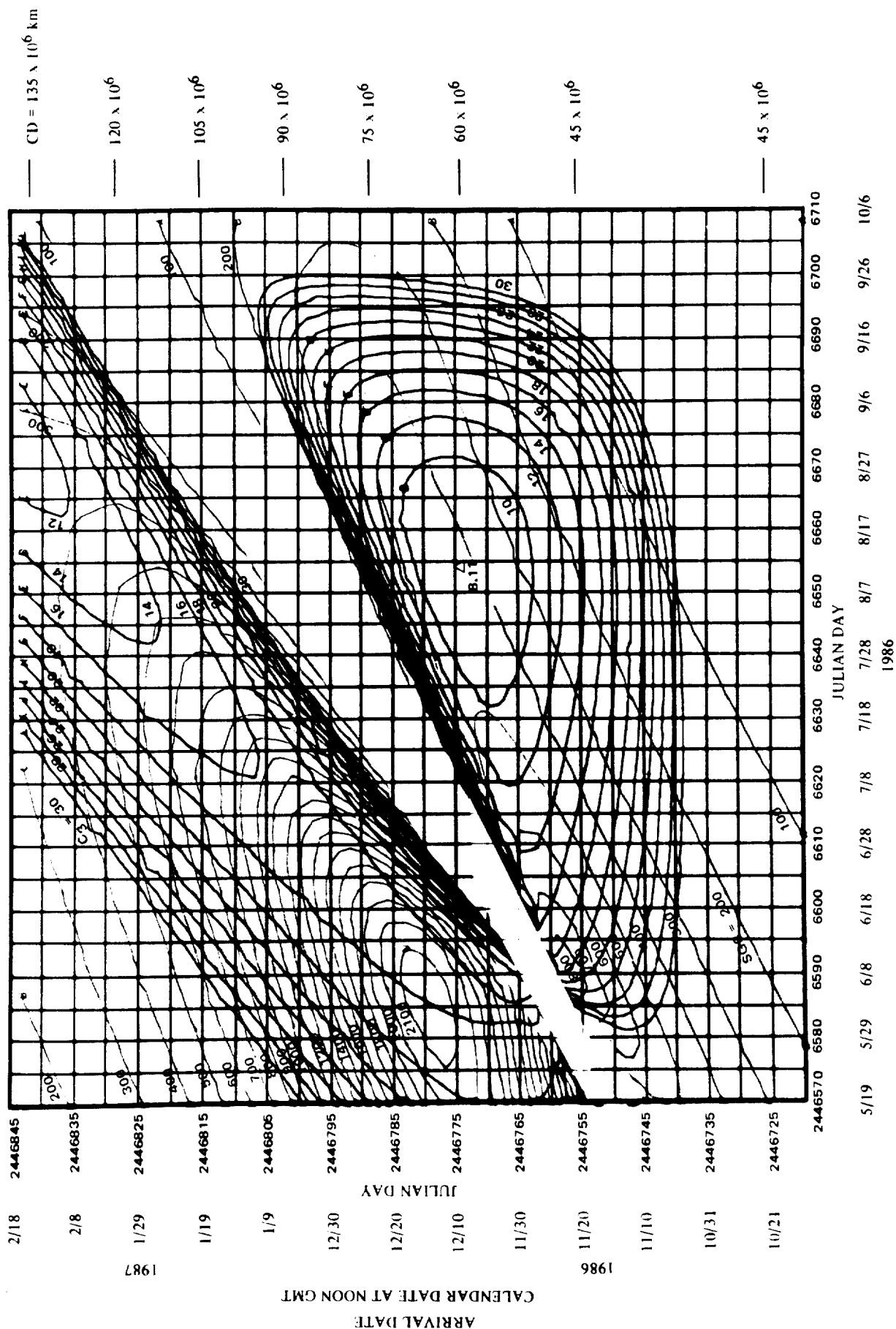




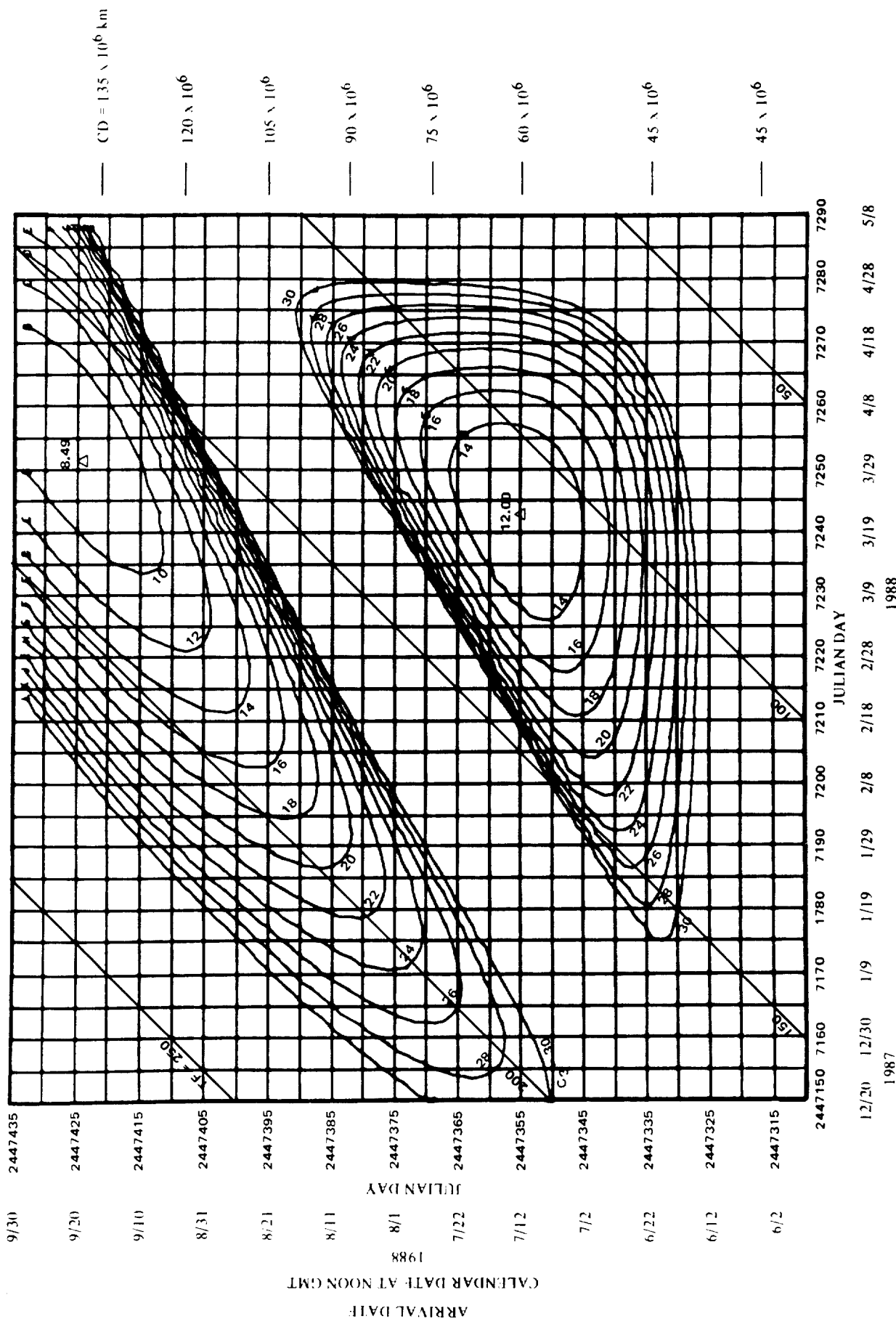
CONTOURS OF C_3 AND TRAJECTORIES FROM EARTH TO VENUS 1986

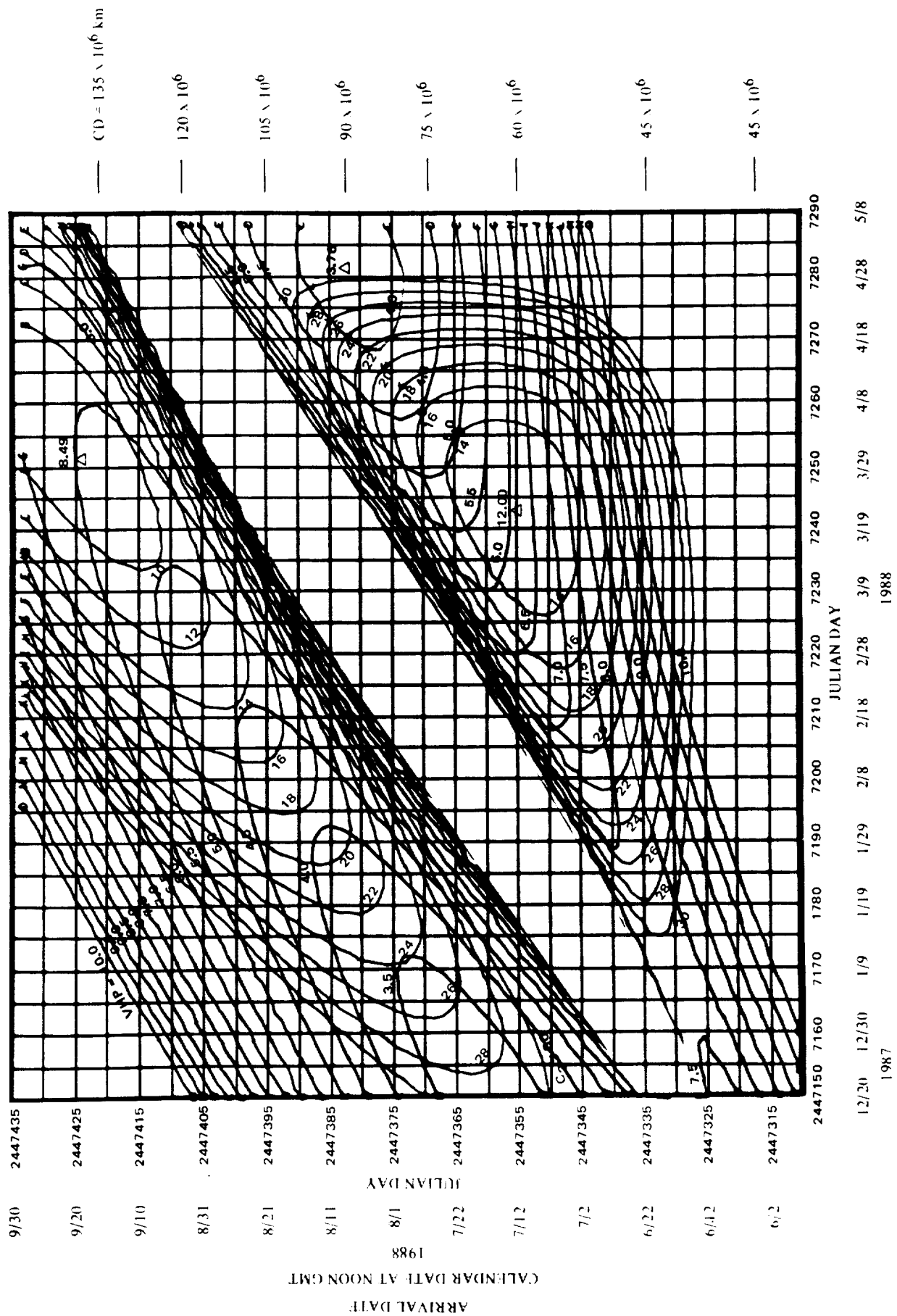




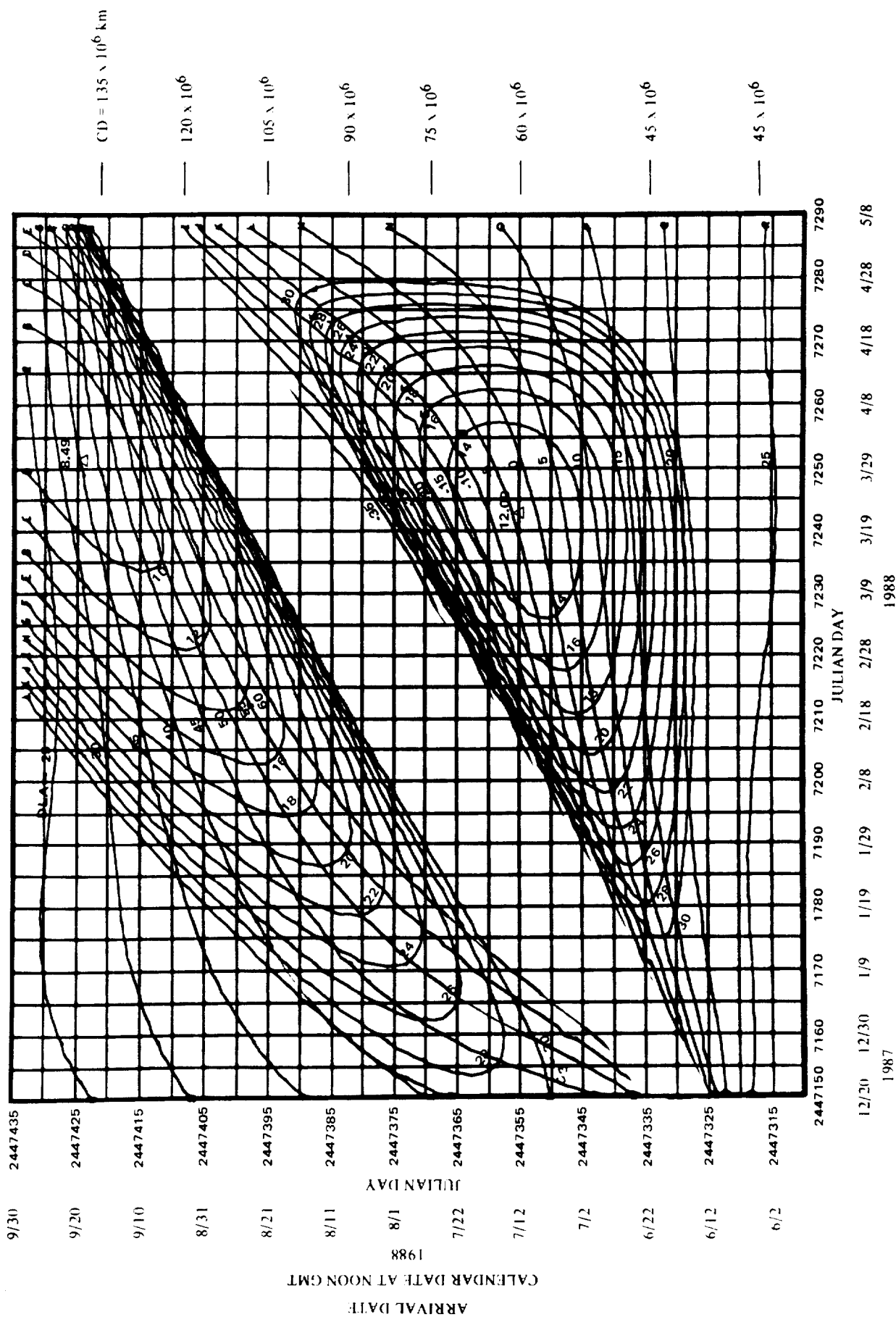


CONTOURS OF C₃ AND SG3 EARTH TO VENUS 1986





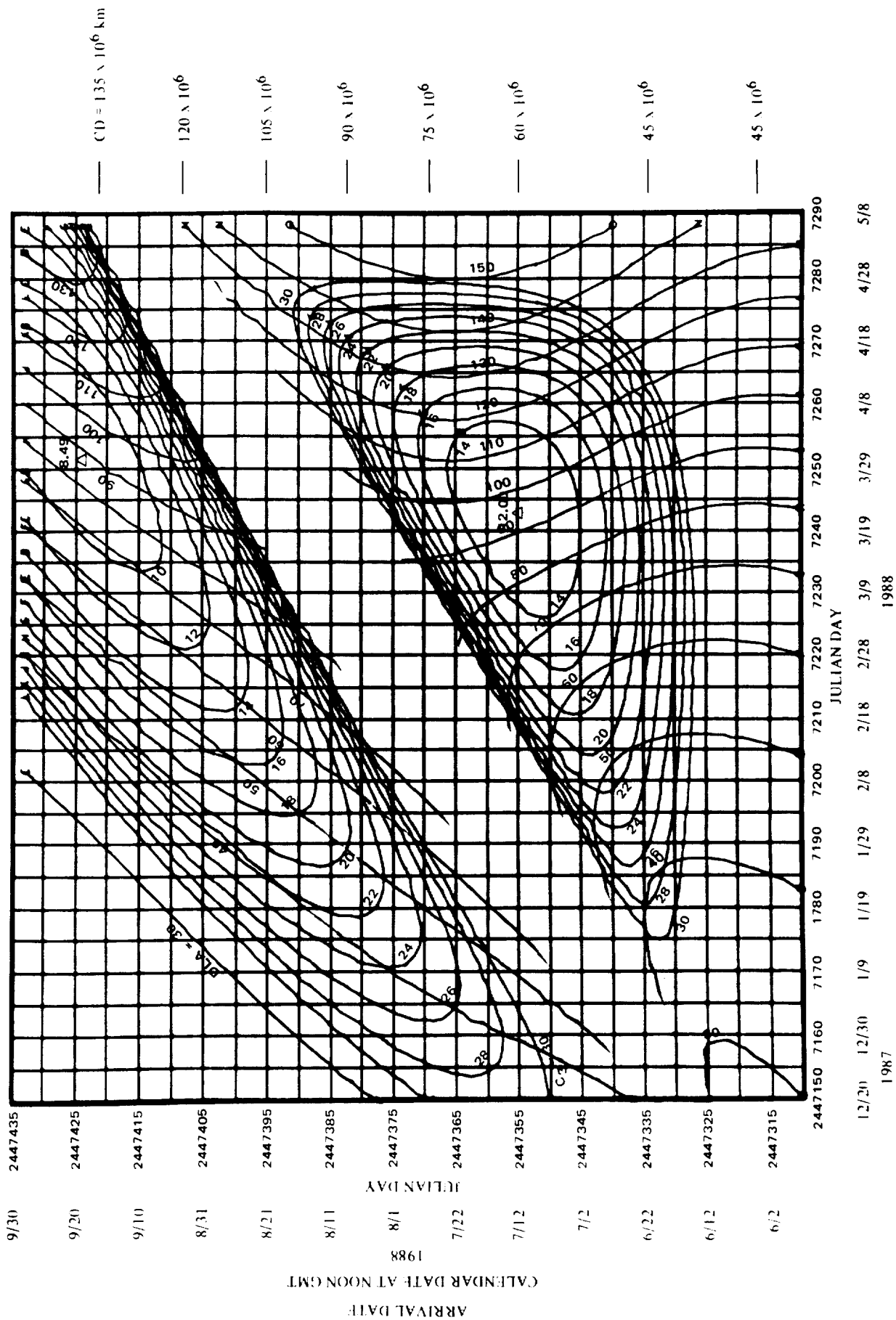
CONTOURS OF C_3 AND VHP EARTH TO VENUS 1988

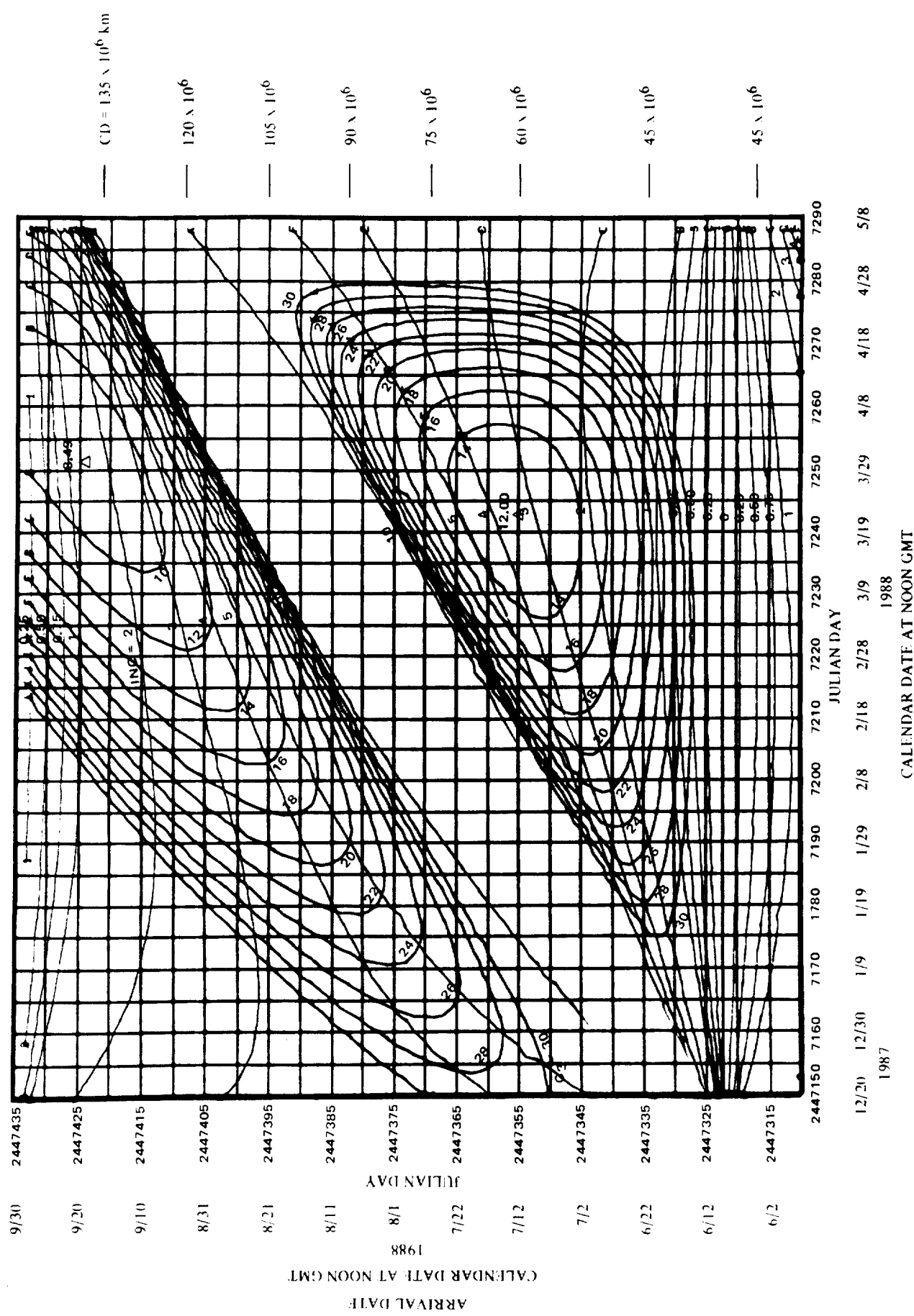


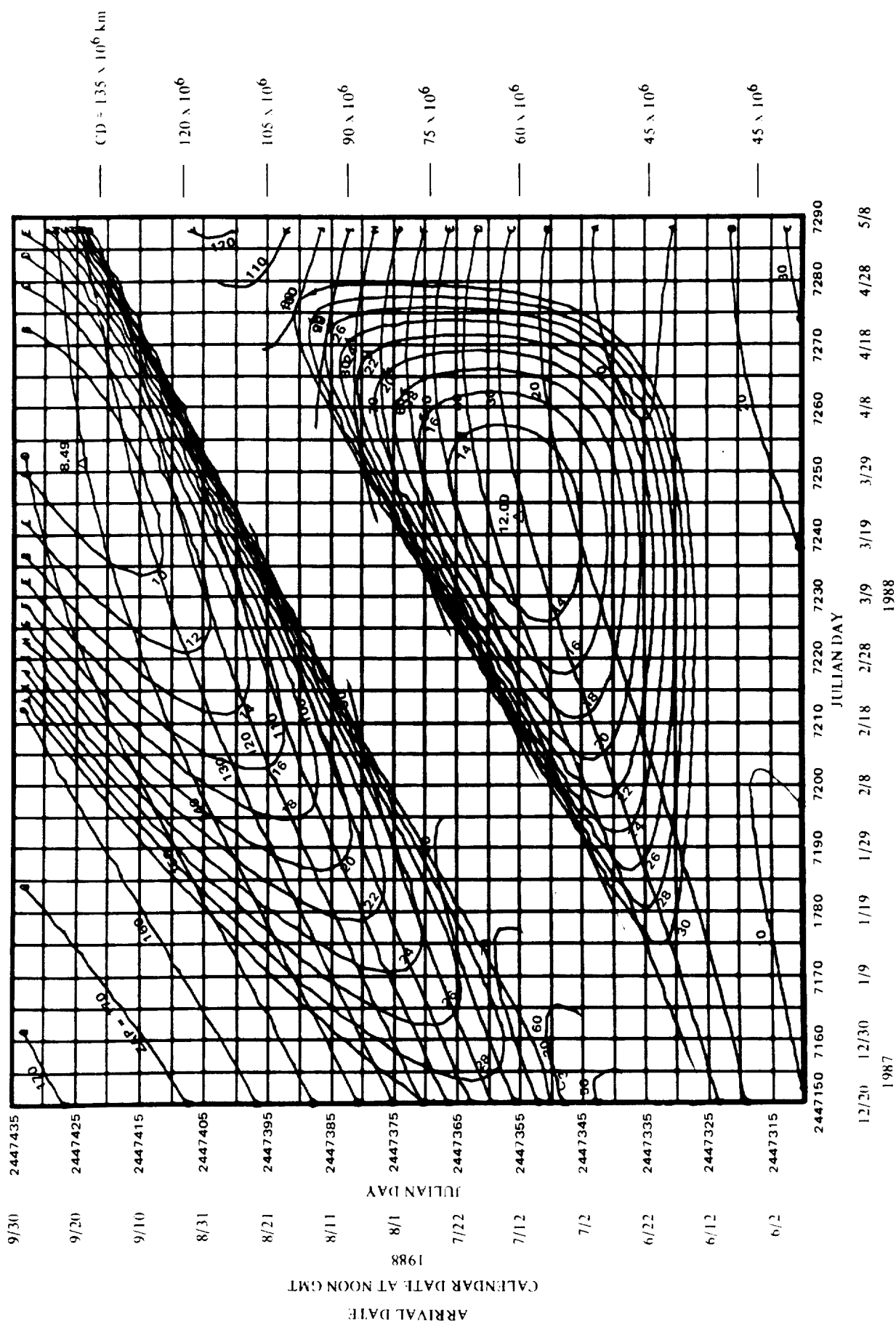
CONTOURS OF C_3 AND DLA EARTH TO VENUS 1988

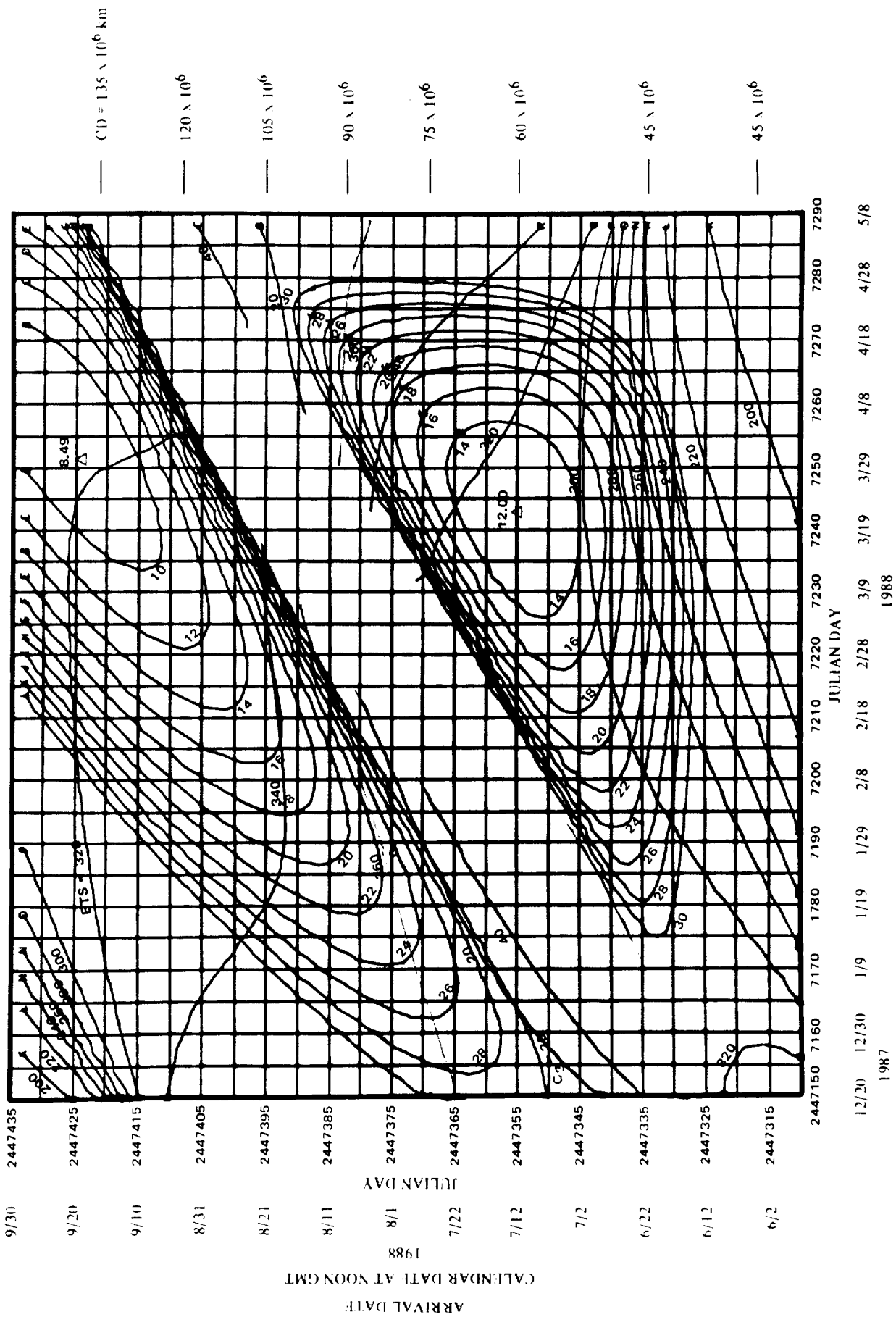
CALENDAR DATE AT NOON GMT

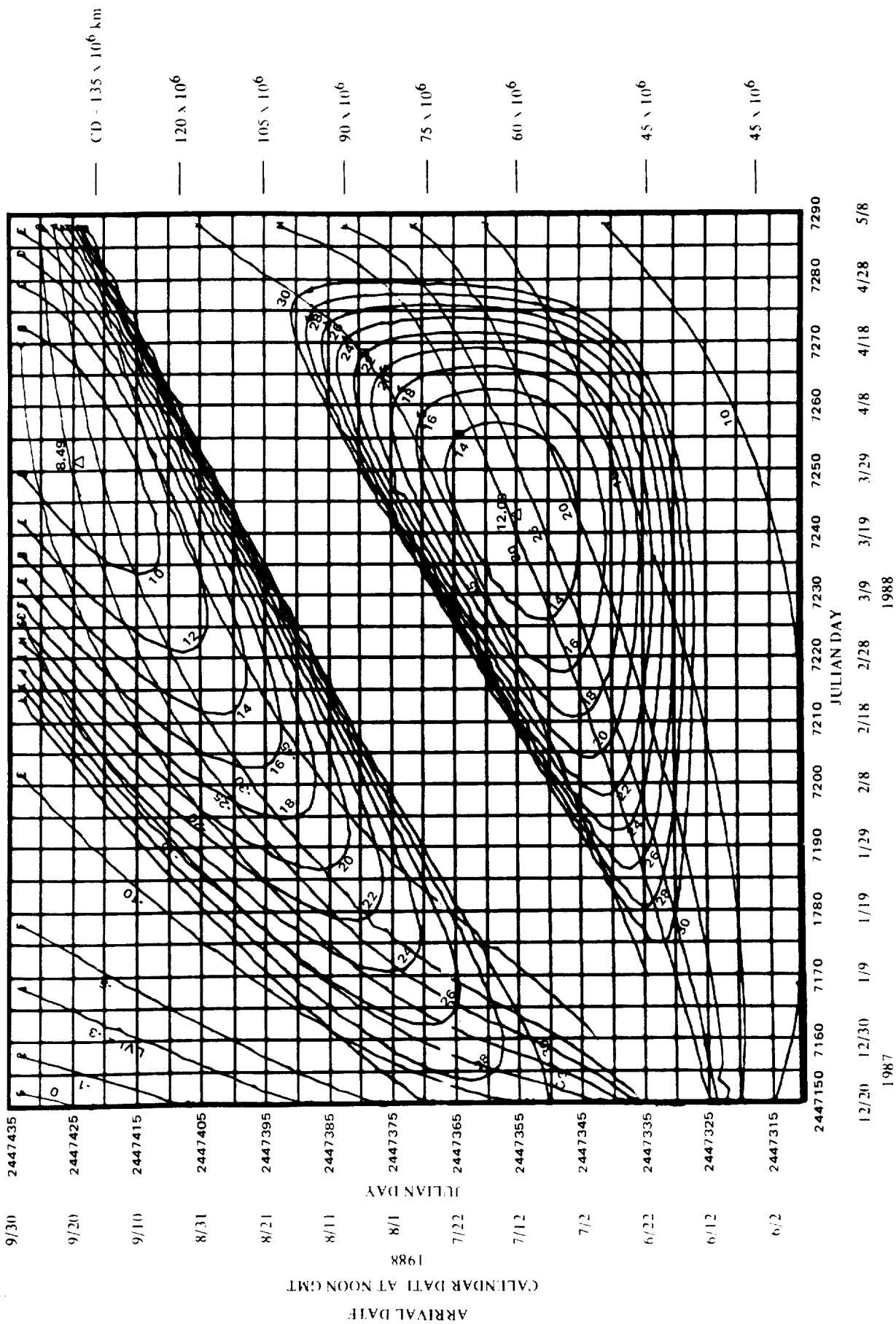
DEPARTURE DATE







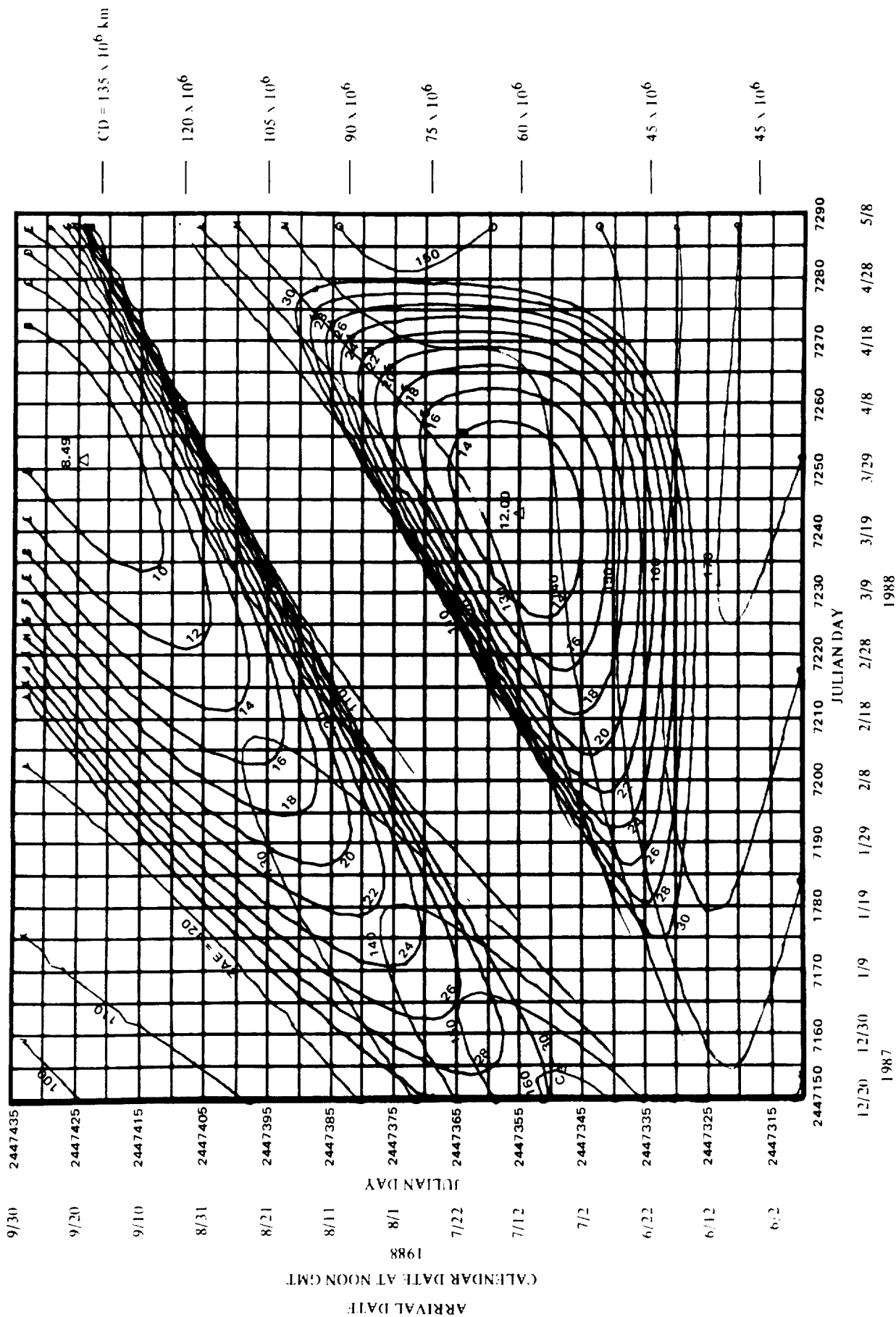




CONTOURS OF C_3 AND LVI EARTH TO VENUS 1988

CALENDAR DATE AT NOON GMT

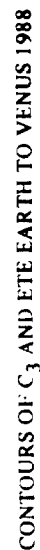
DEPARTURE DATE

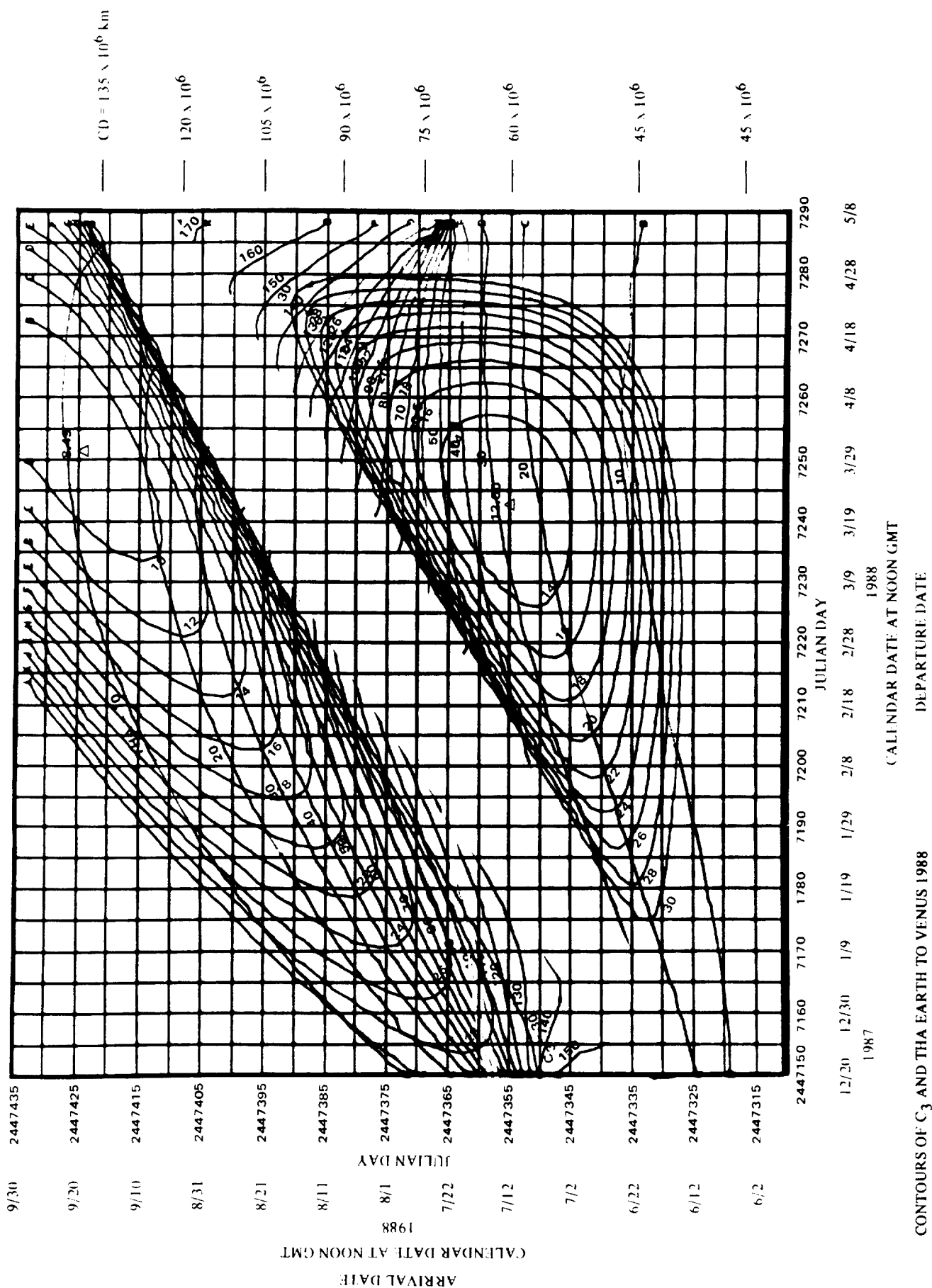


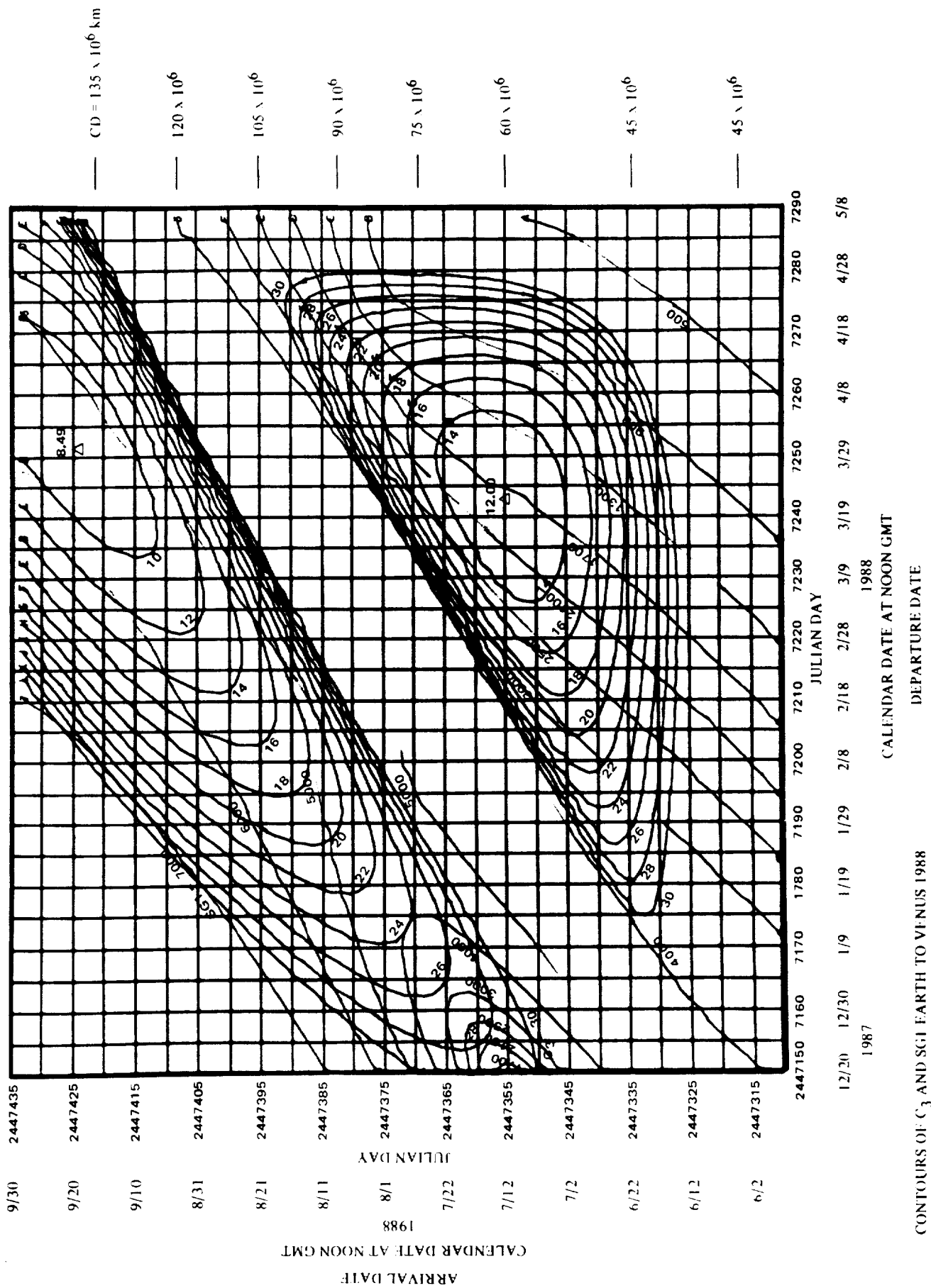
CONTOURS OF C_3 AND ZAF EARTH TO VENUS 1988

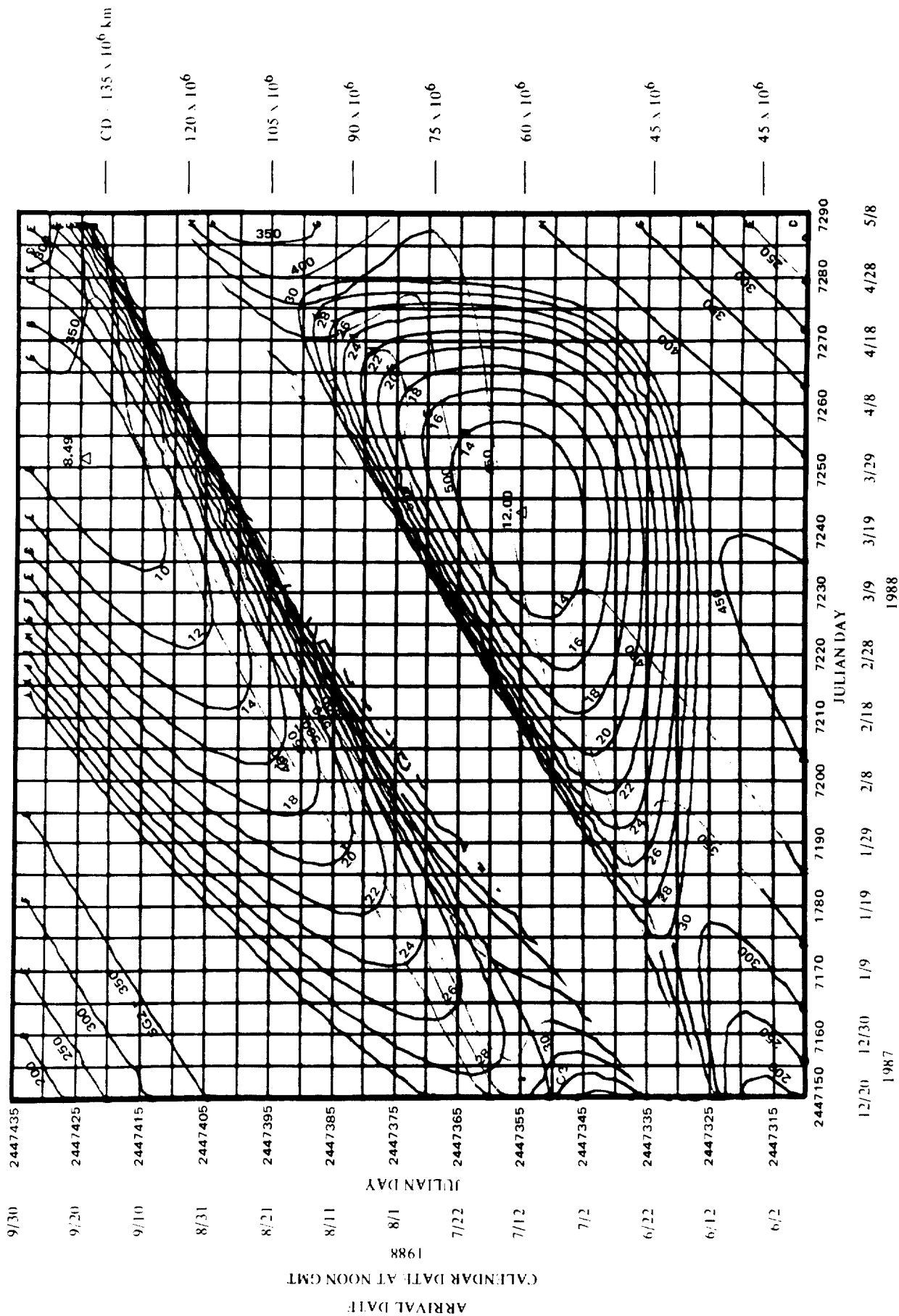
CALENDAR DATE AT NOON GMT

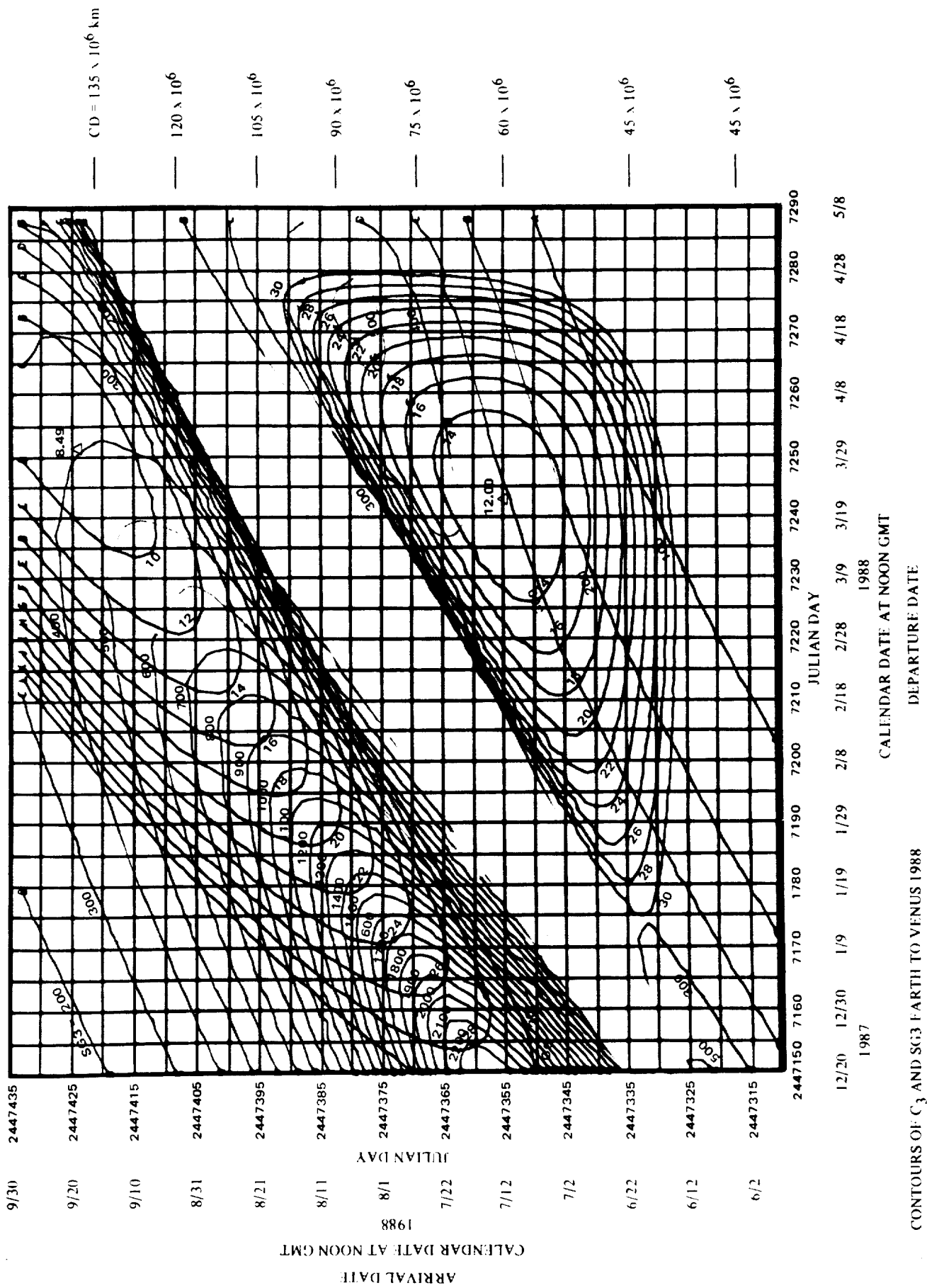
DEPARTURE DATE

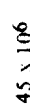




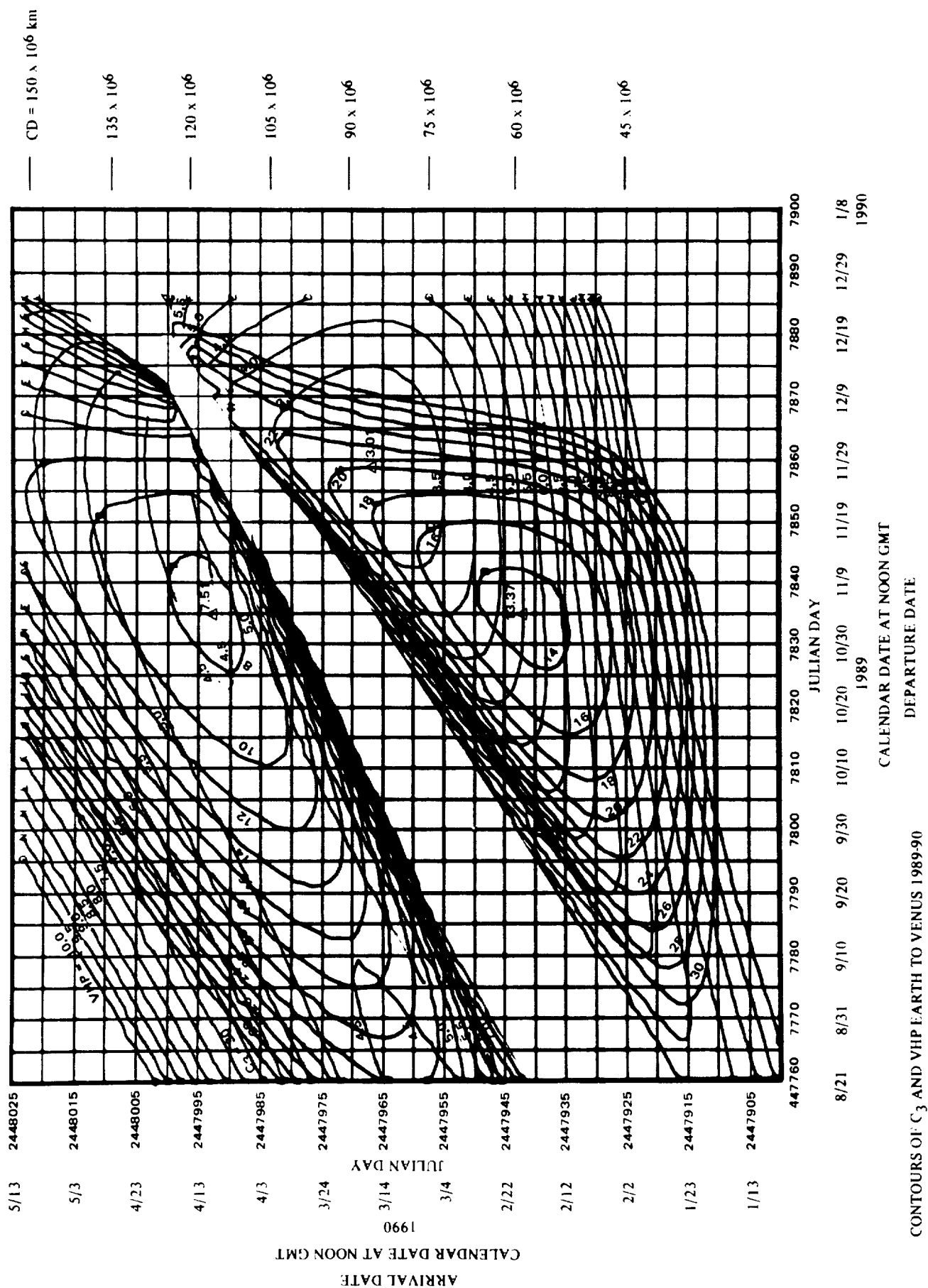


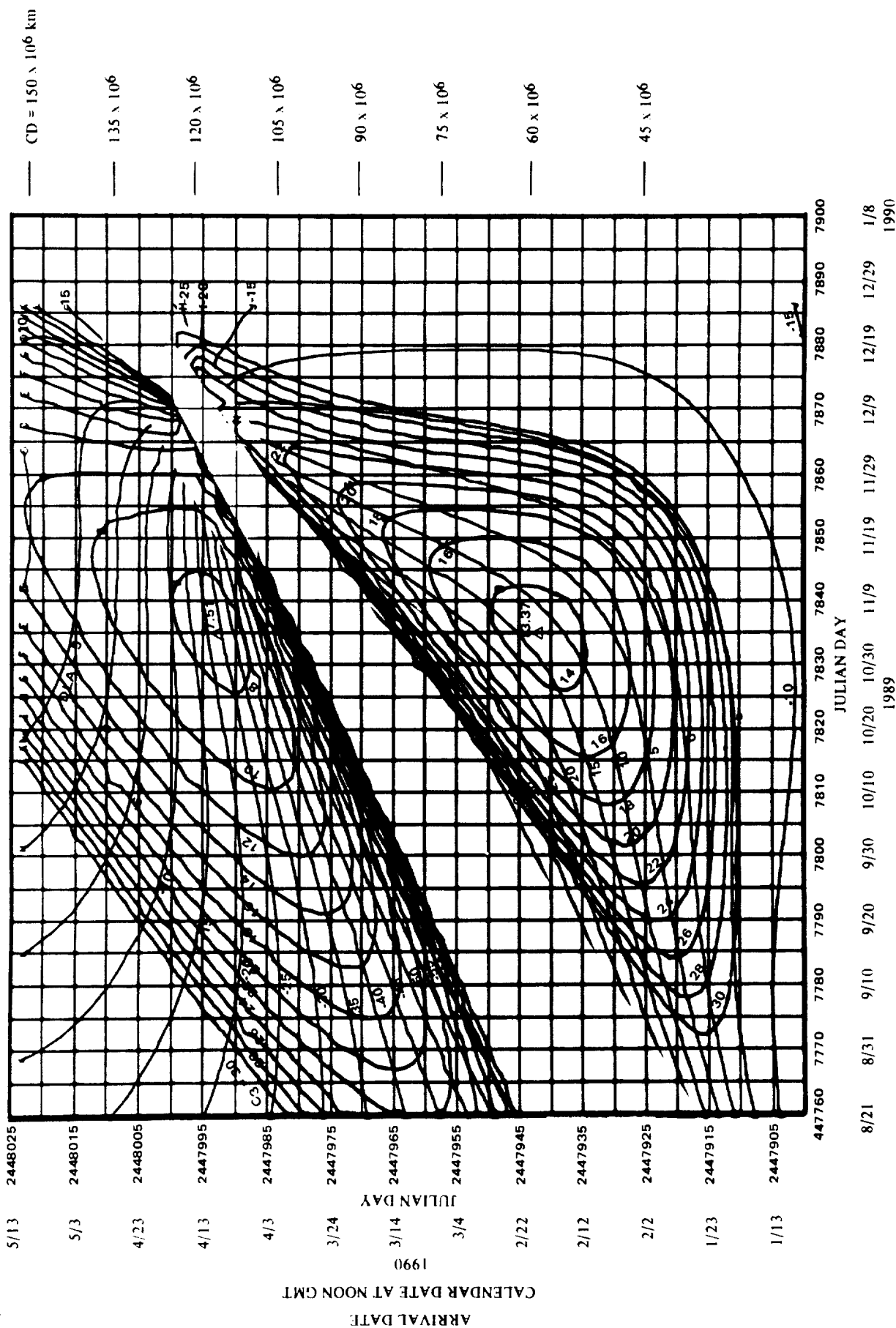




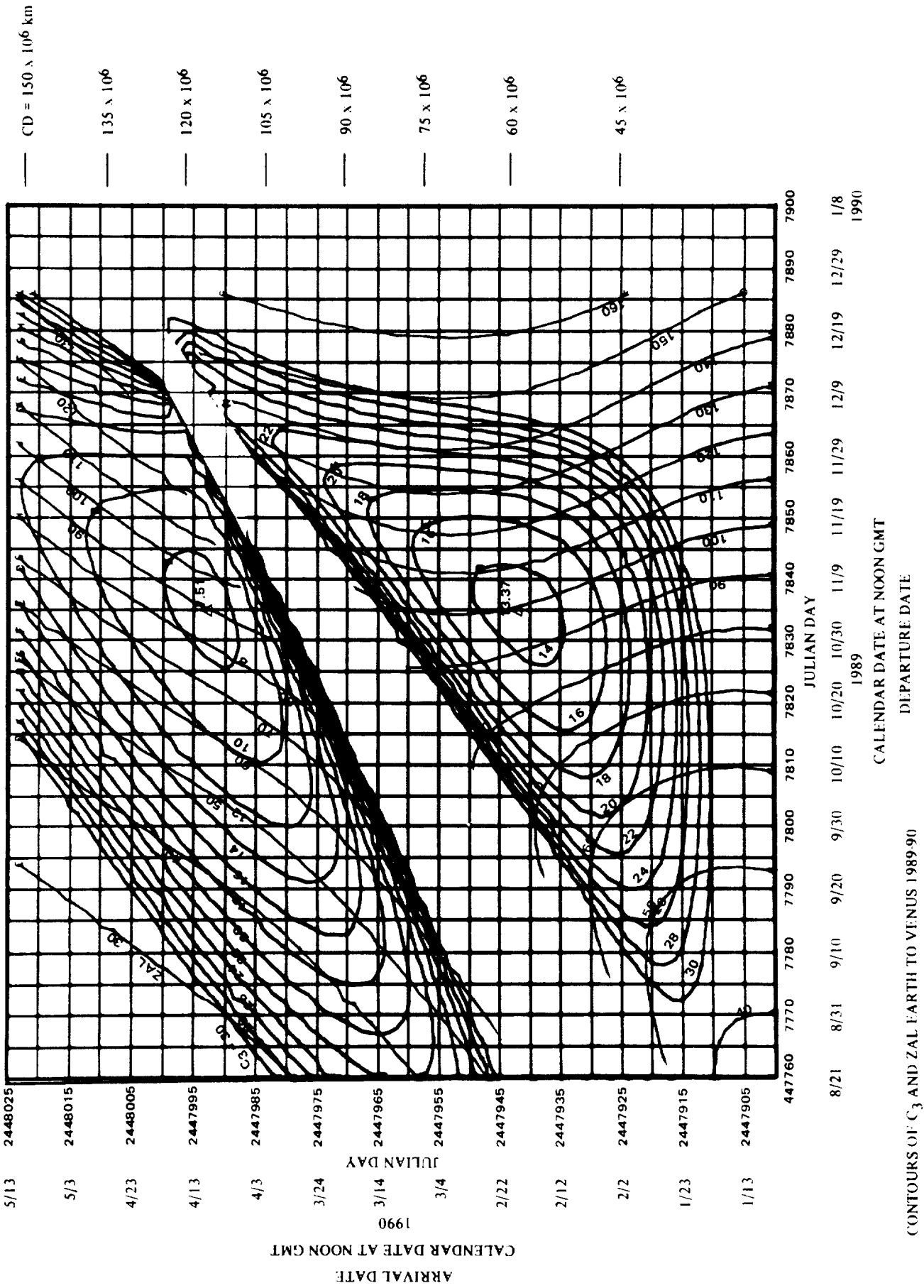


DEPARTURE DATE

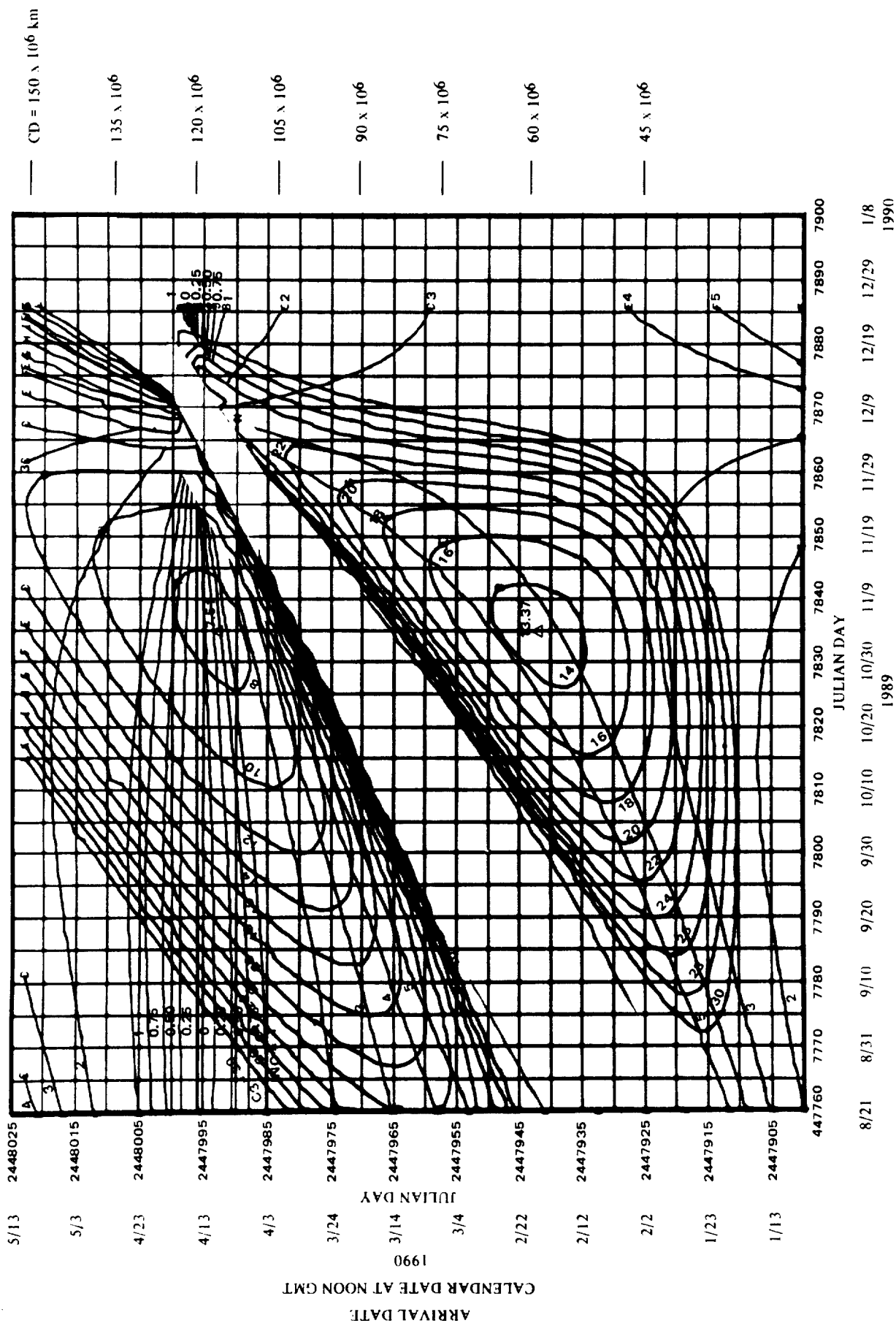




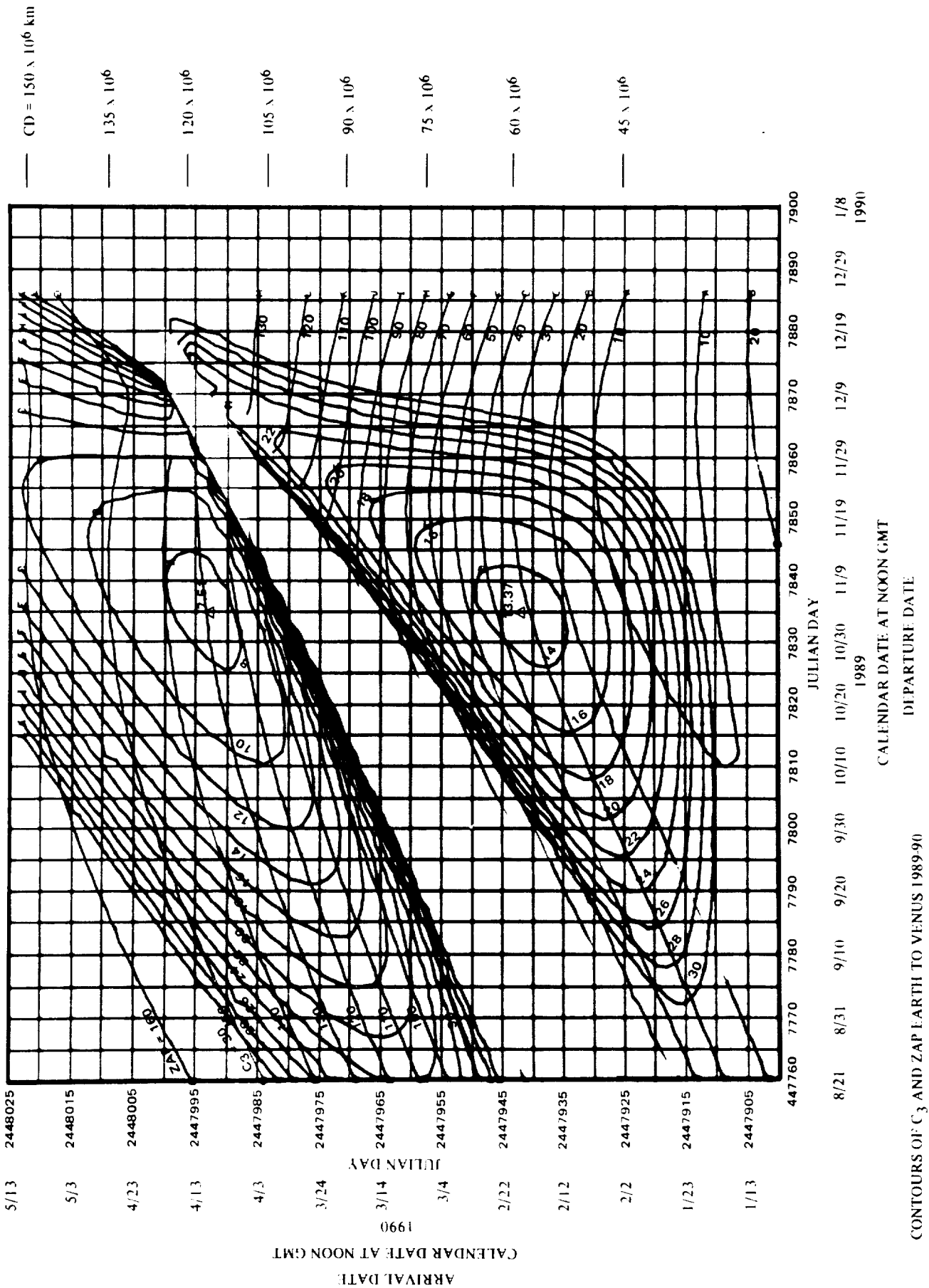
CONTOURS OF C₃ AND DLA EARTH TO VENUS 1989-90

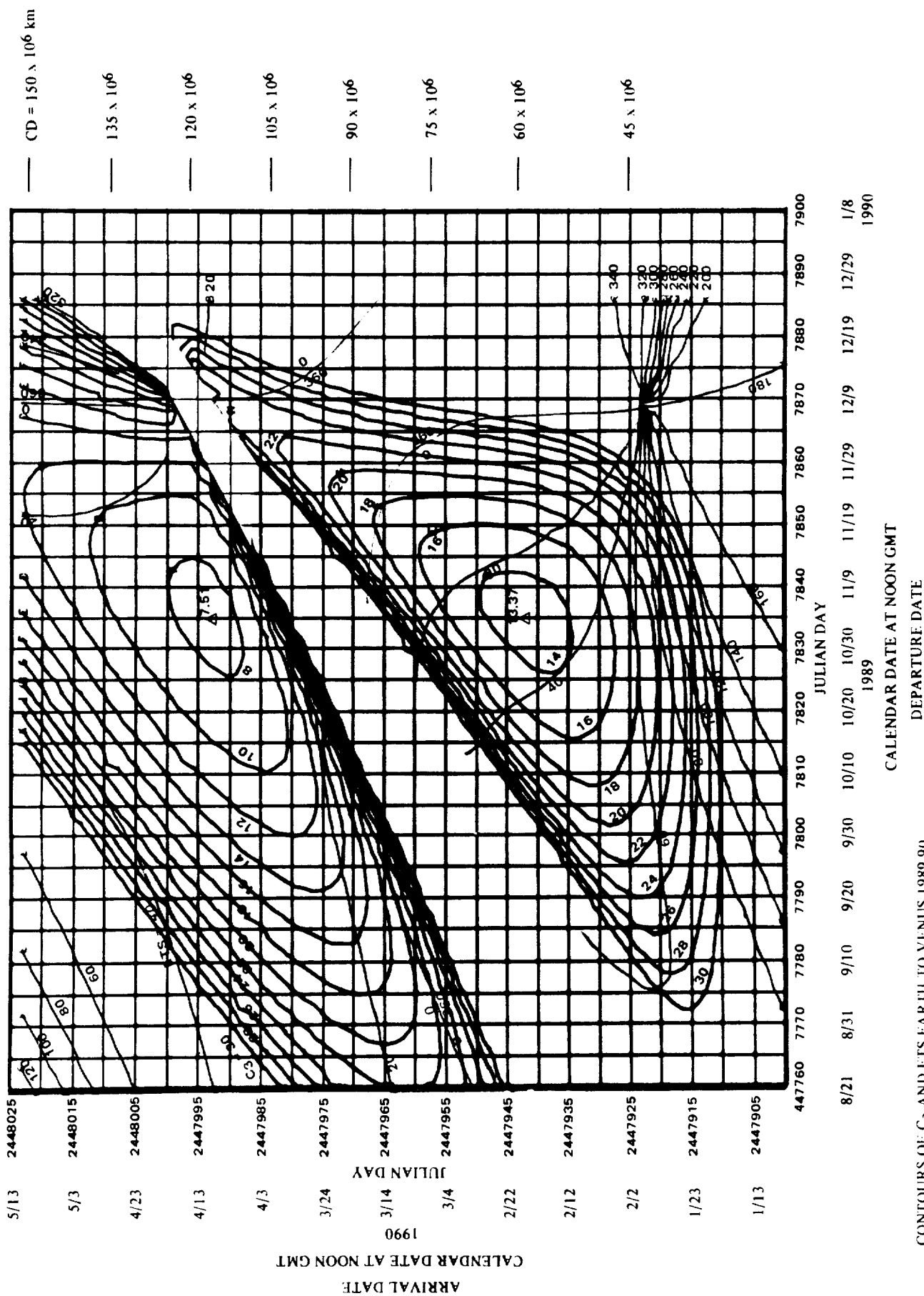


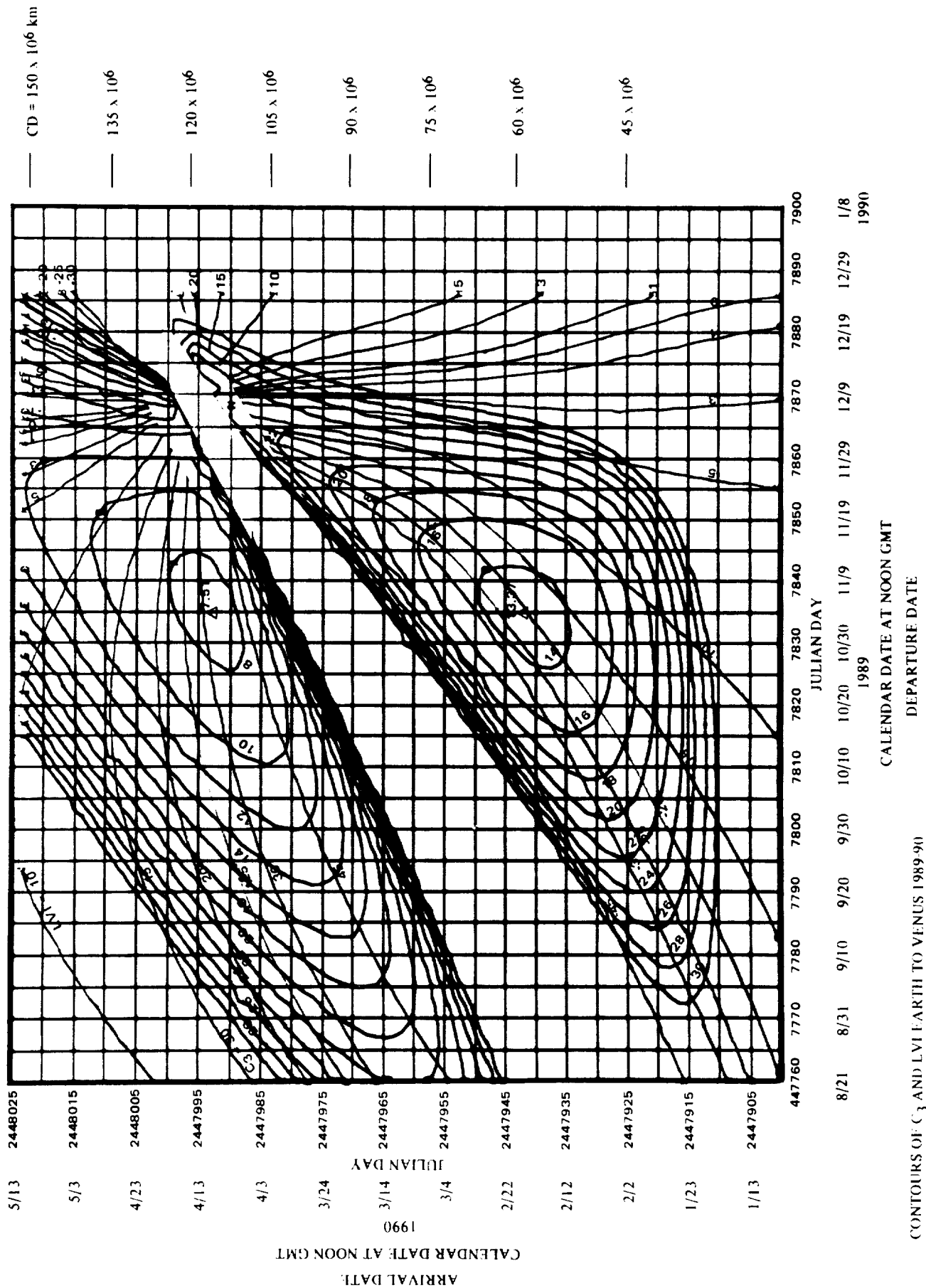
CONTOURS OF C₃ AND ZAL EARTH TO VENUS 1989-90

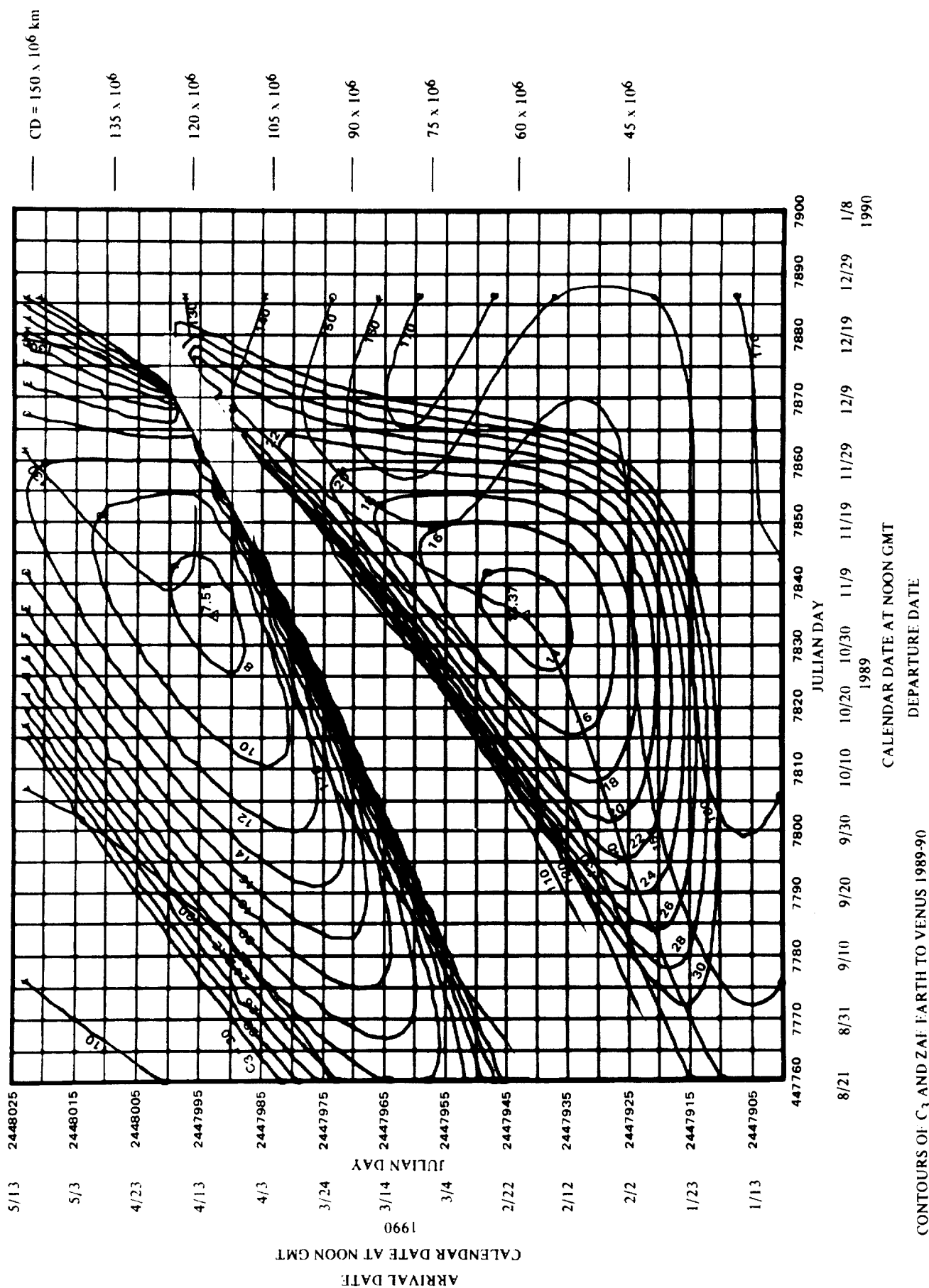


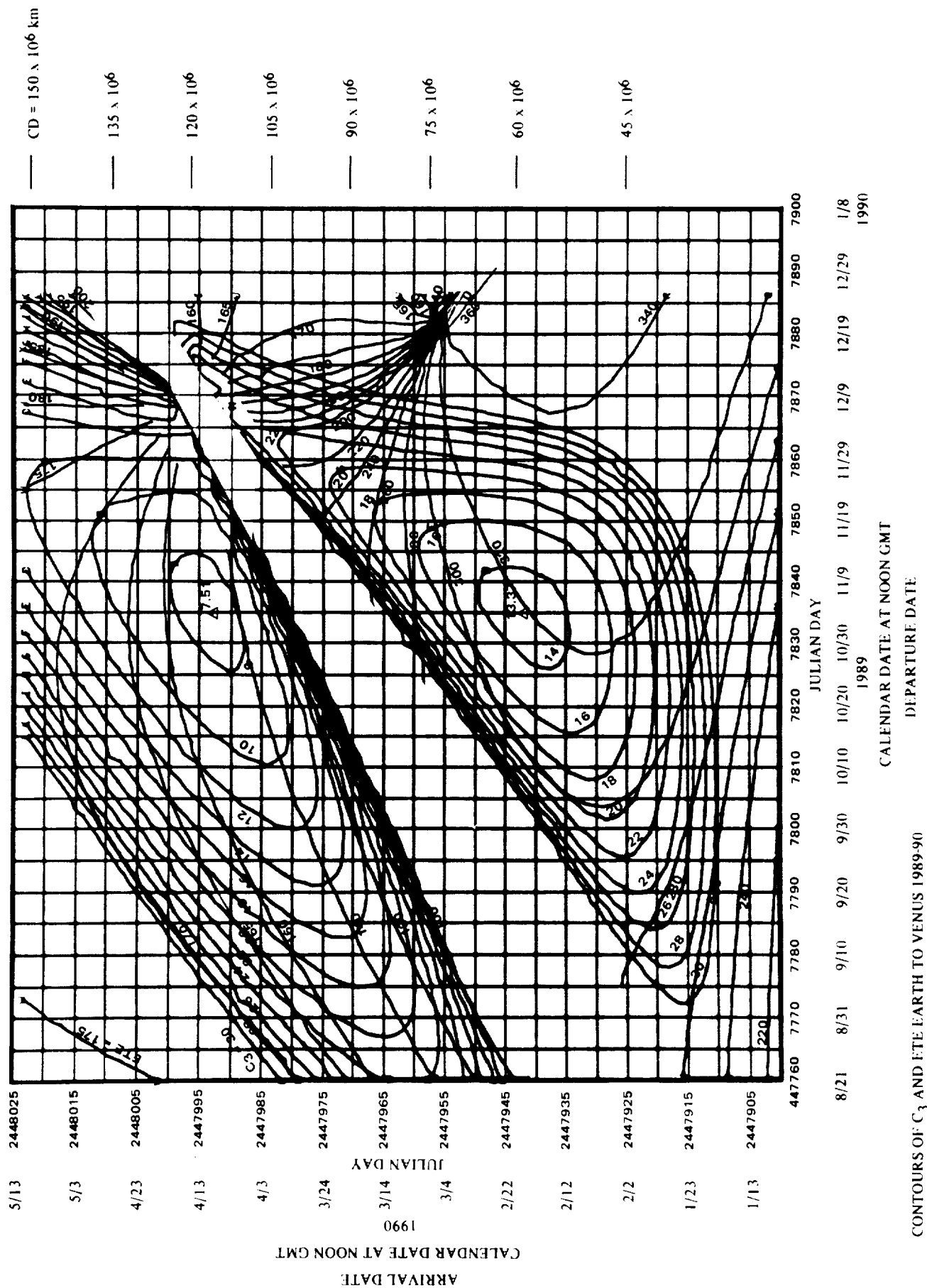
CONTOURS OF C_3 AND INC EARTH TO VENUS 1989-90

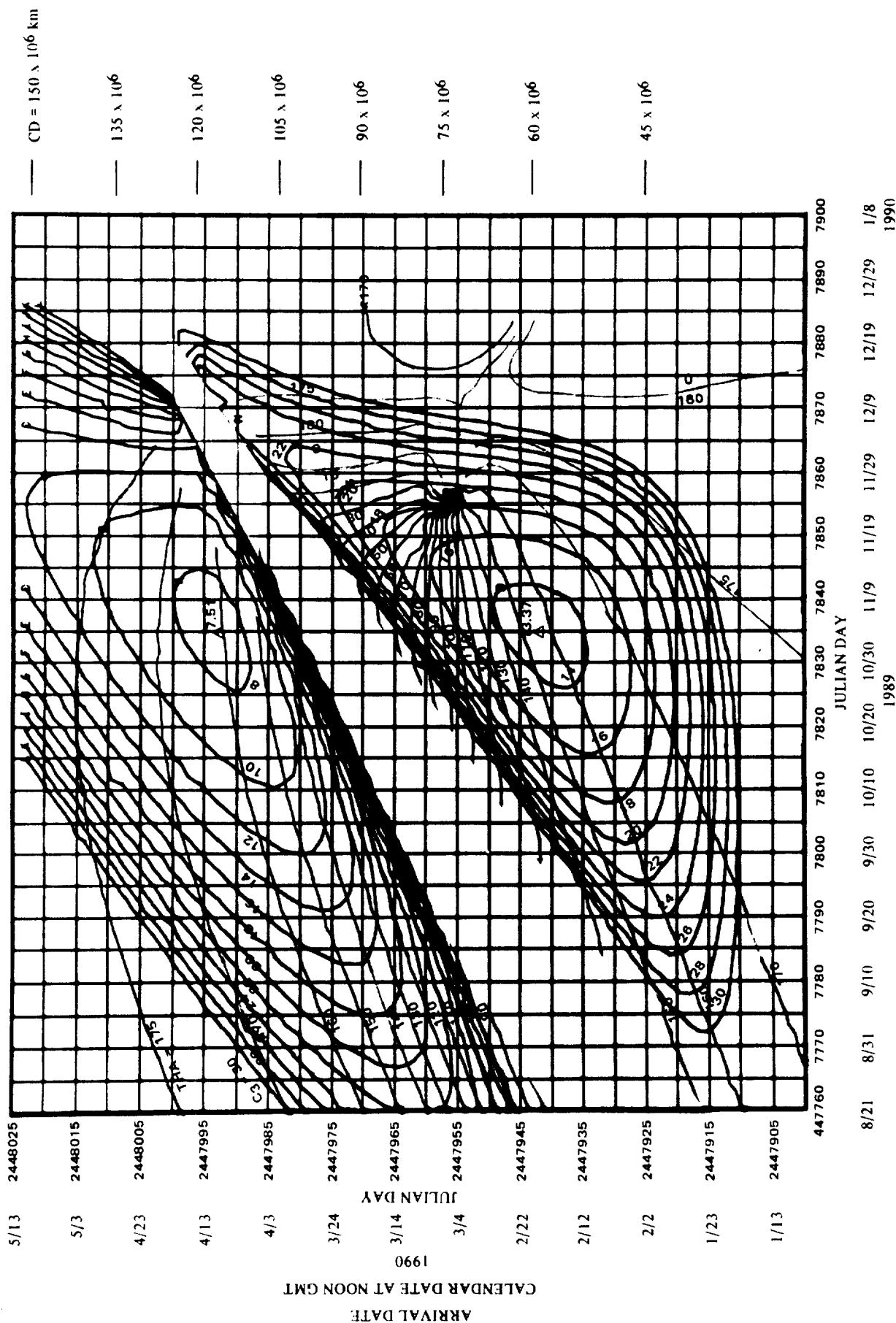


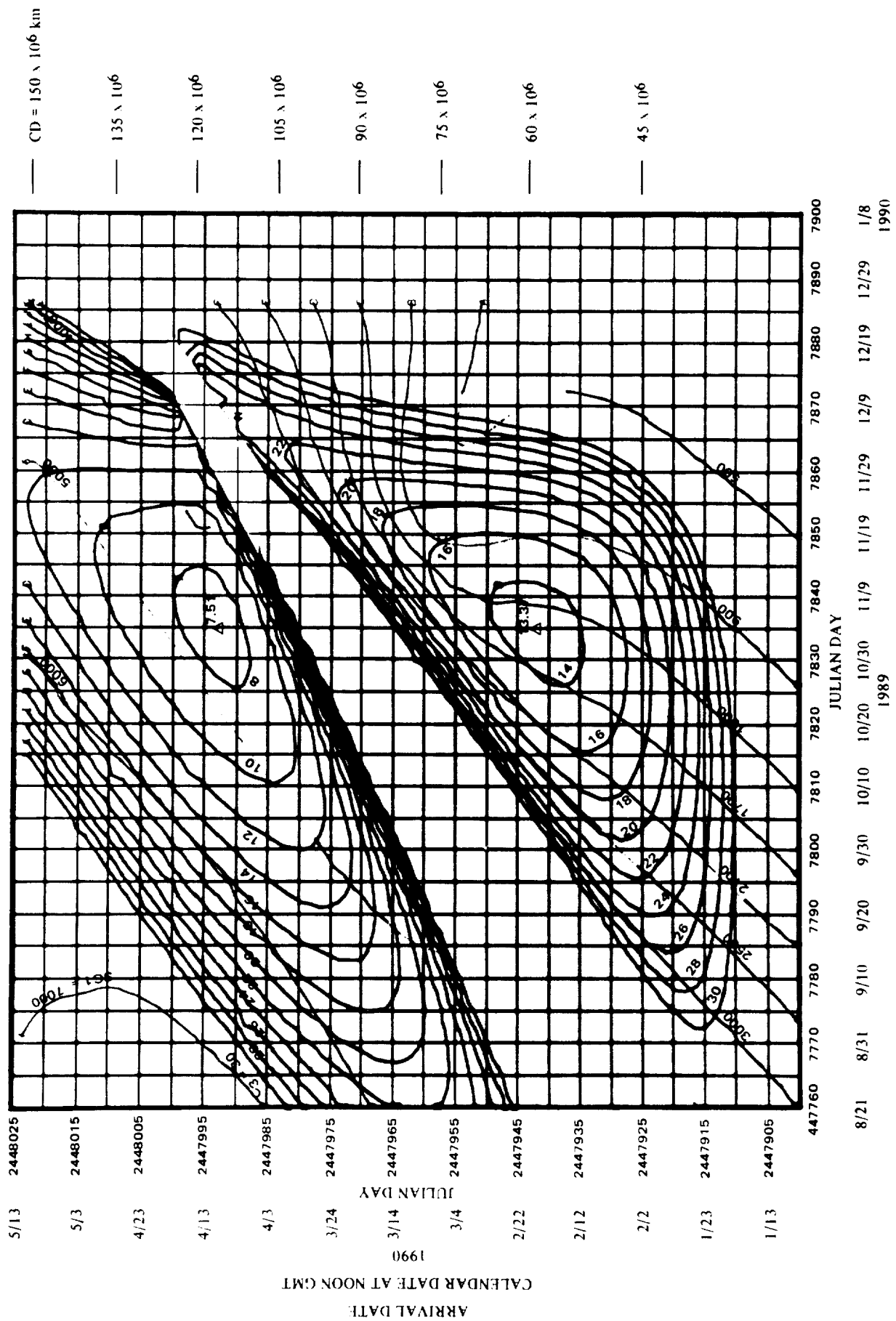


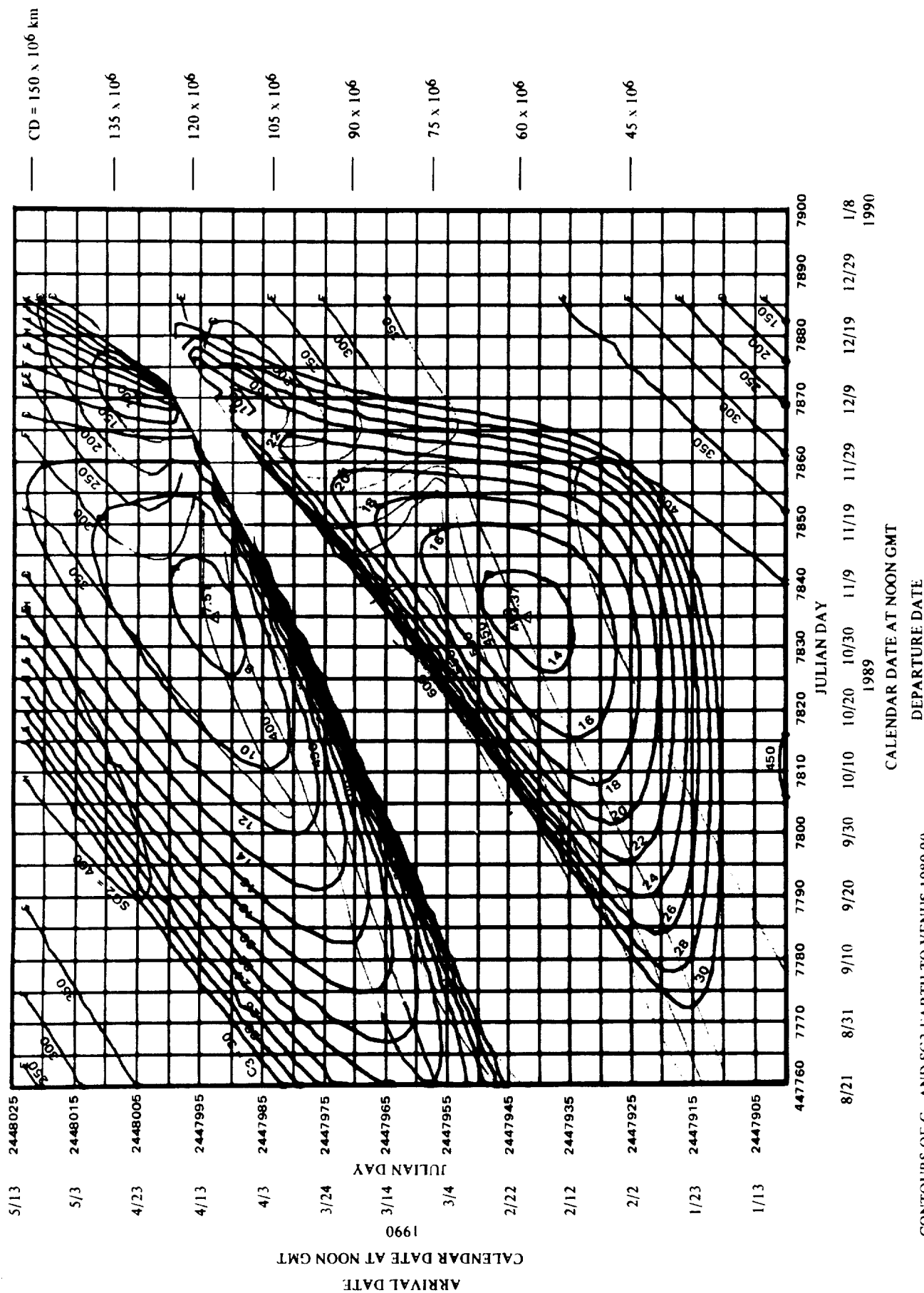










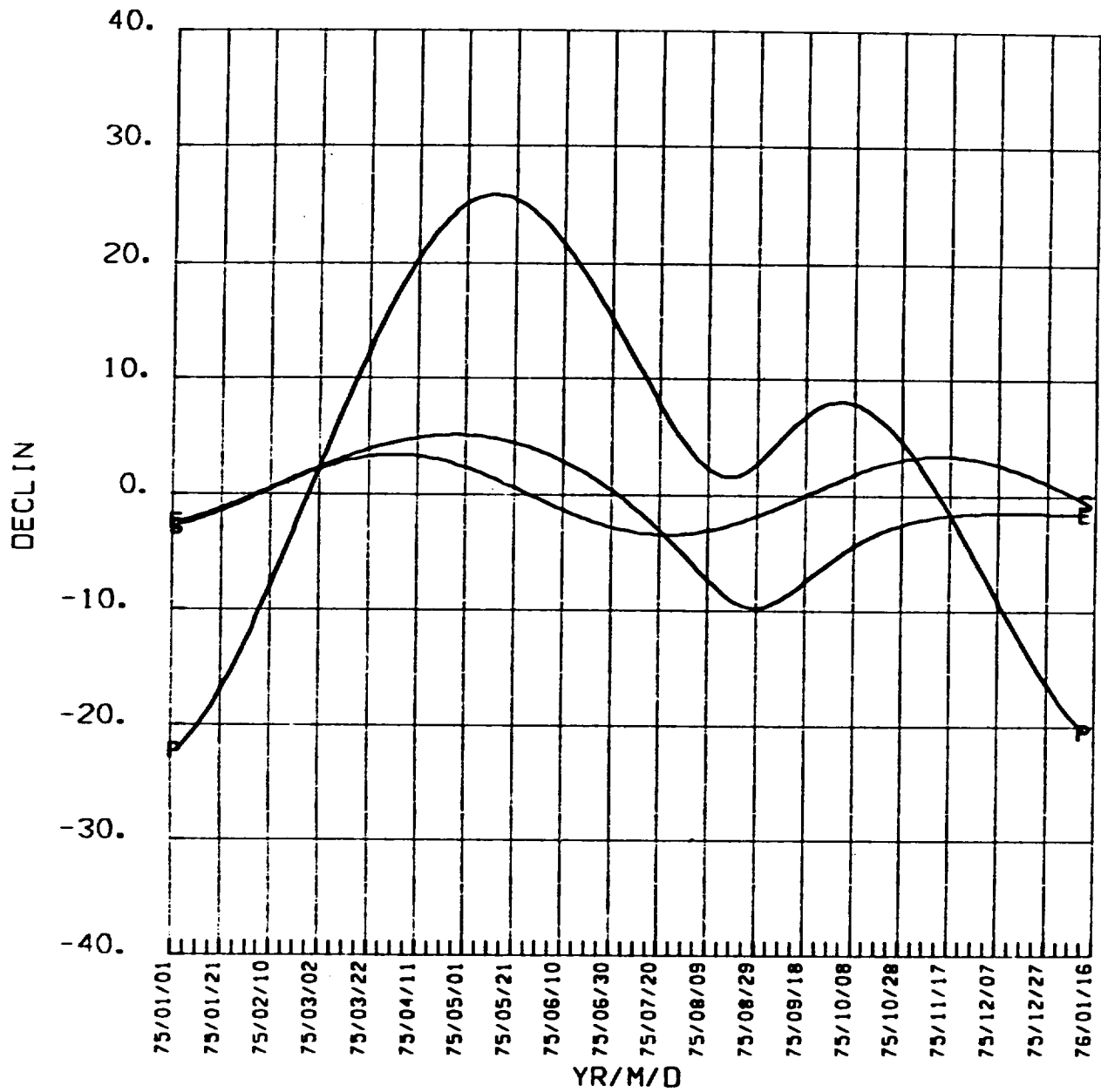


CONTOURS OF C₃ AND SG2 EARTH TO VENUS 1989-90



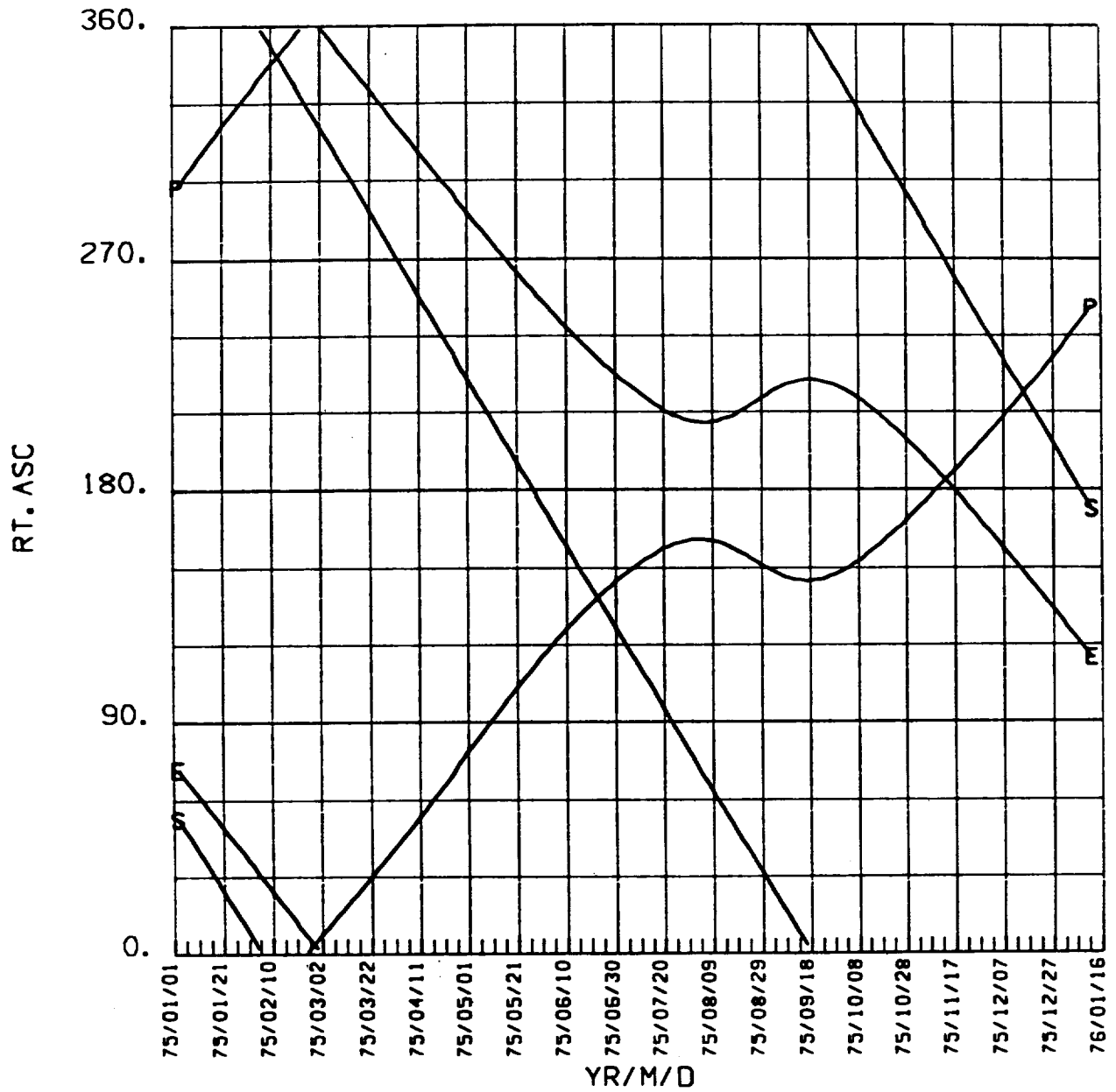
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1975



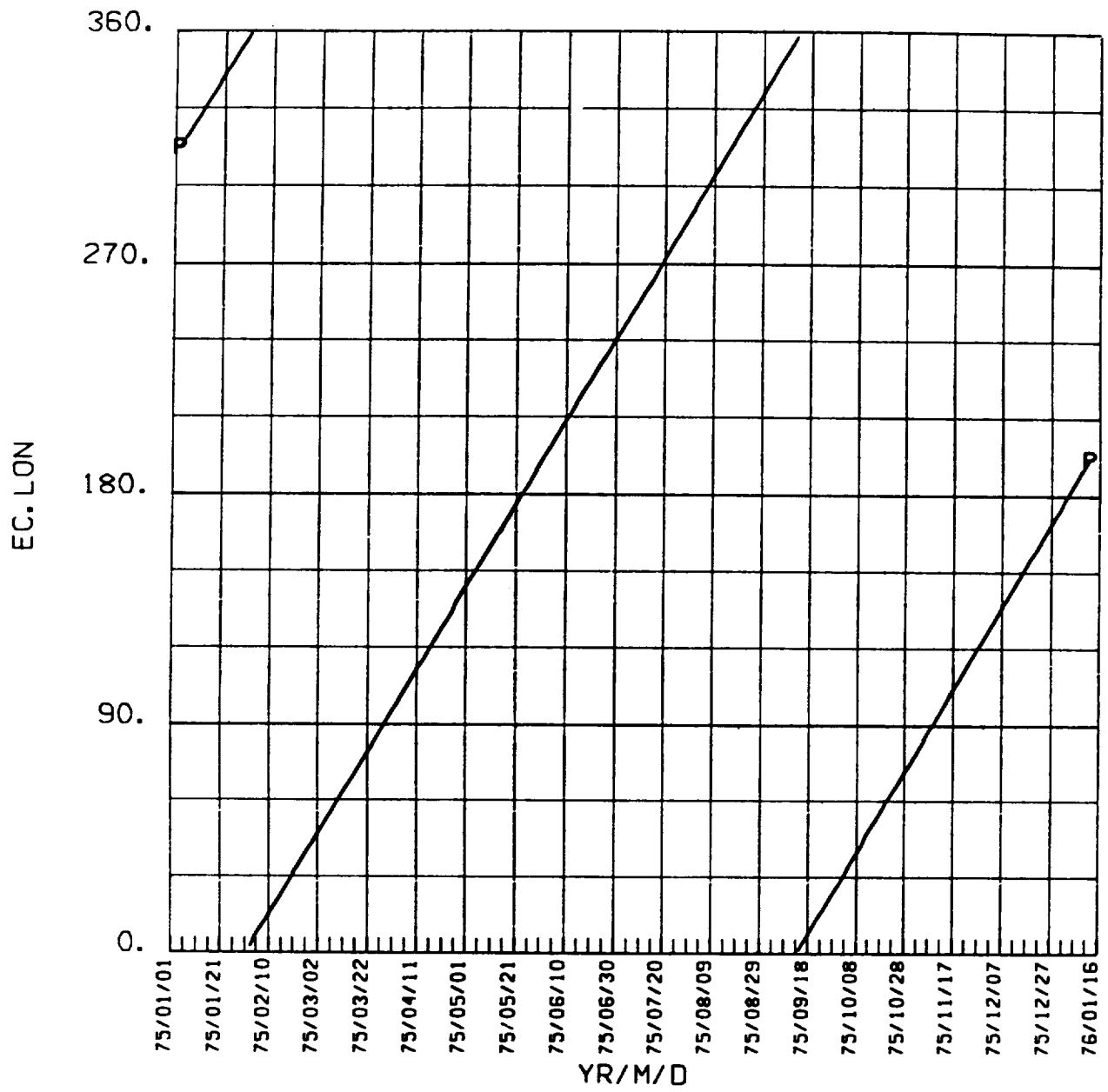
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1975



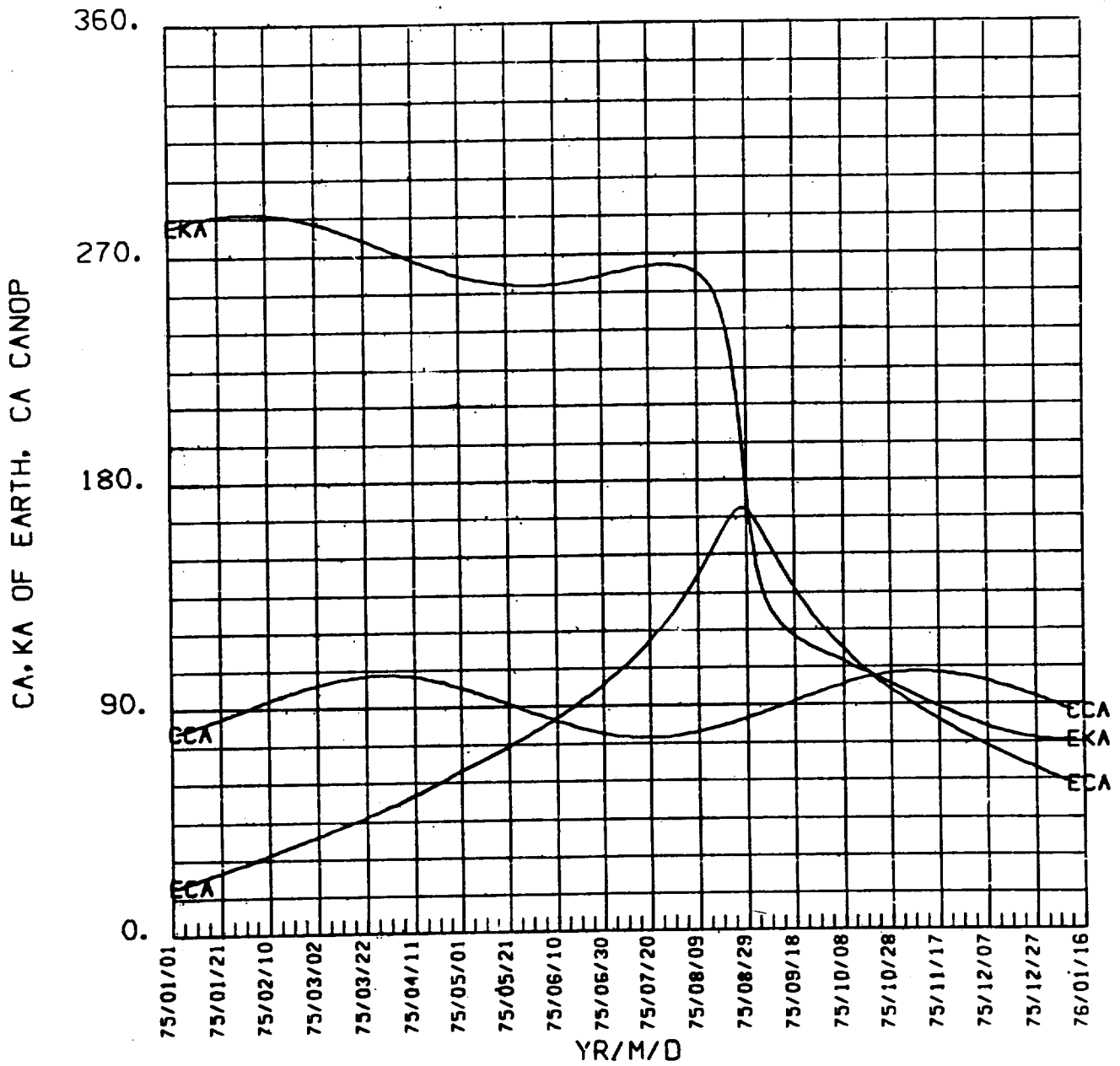
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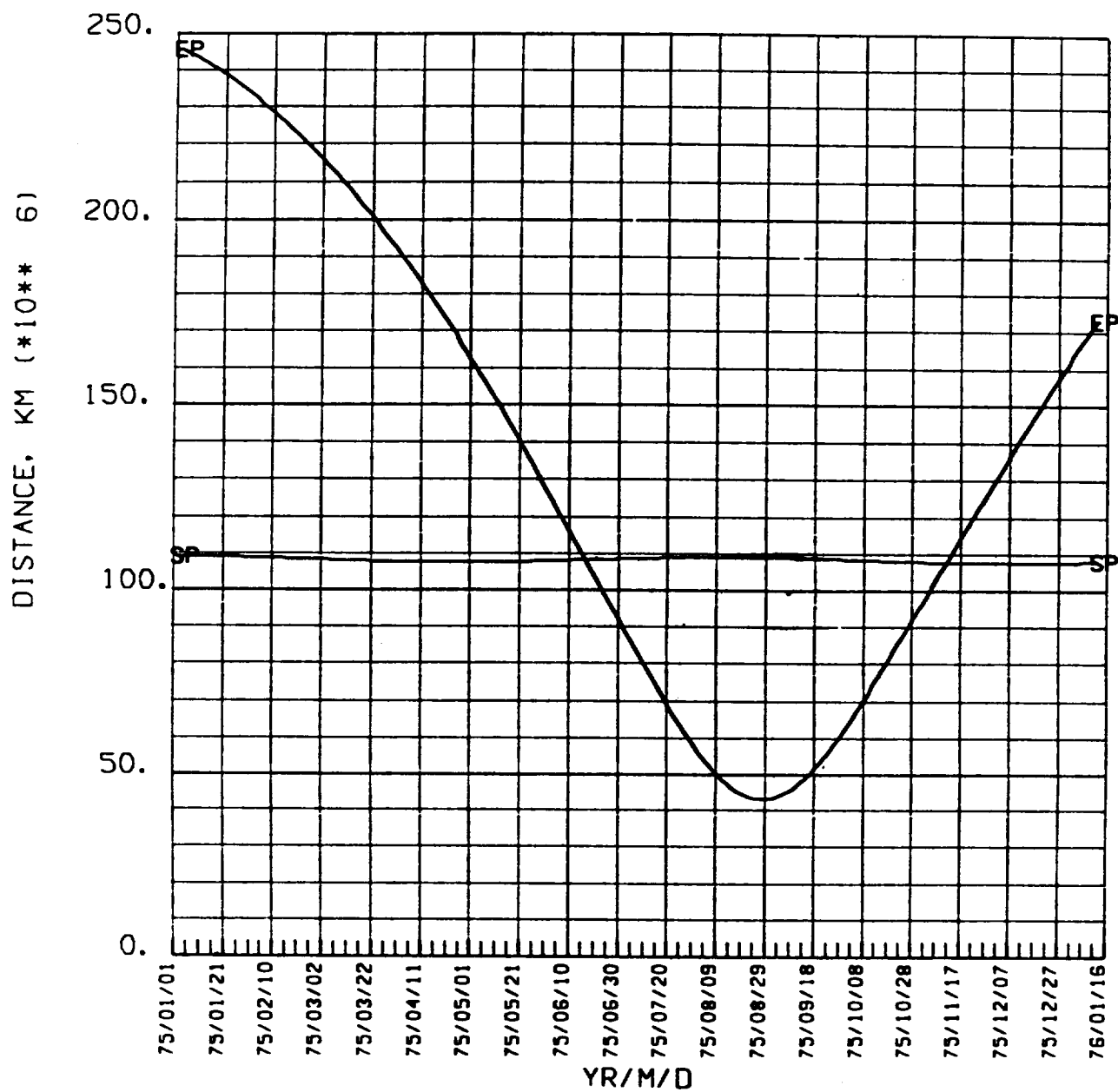
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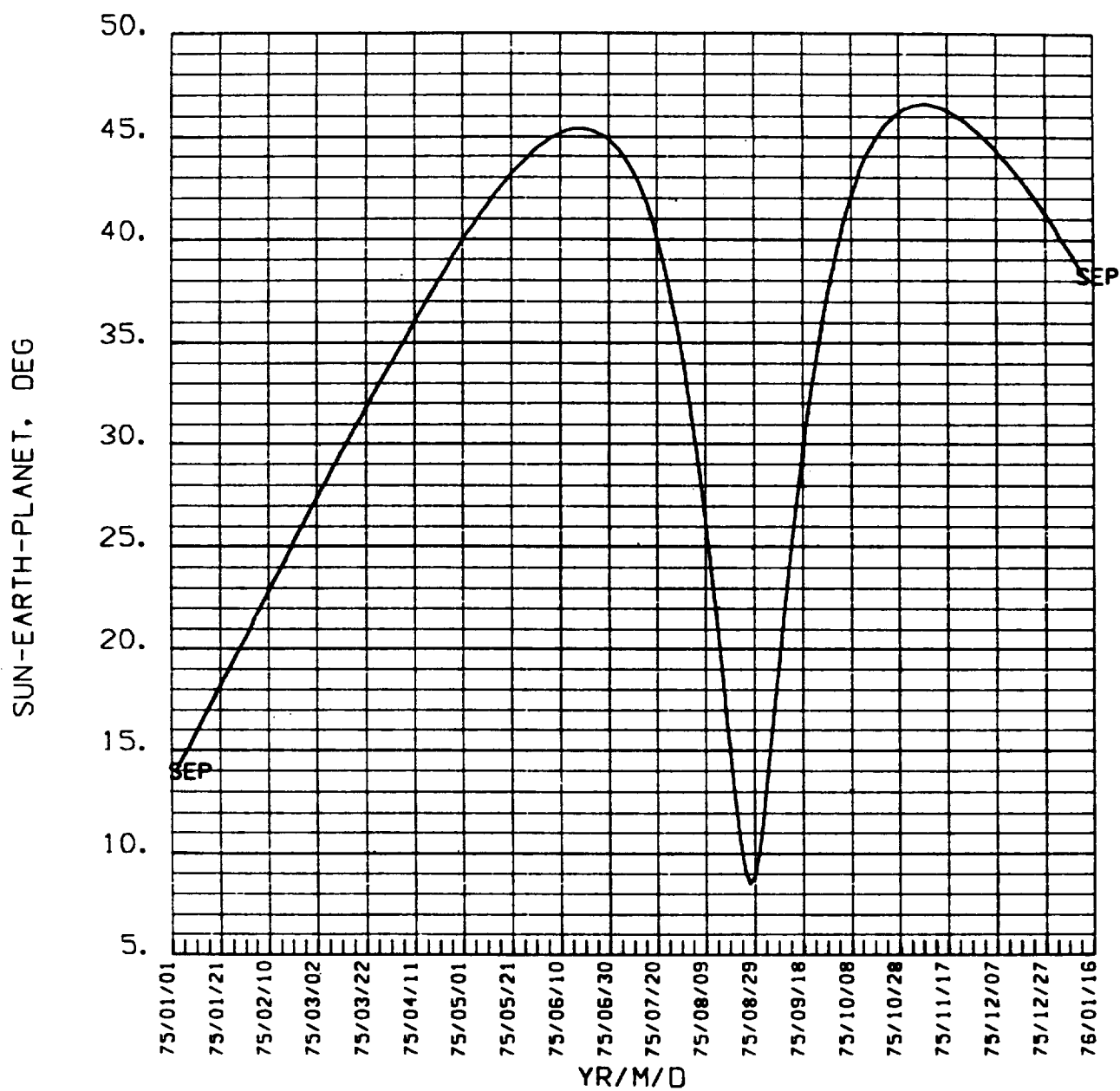


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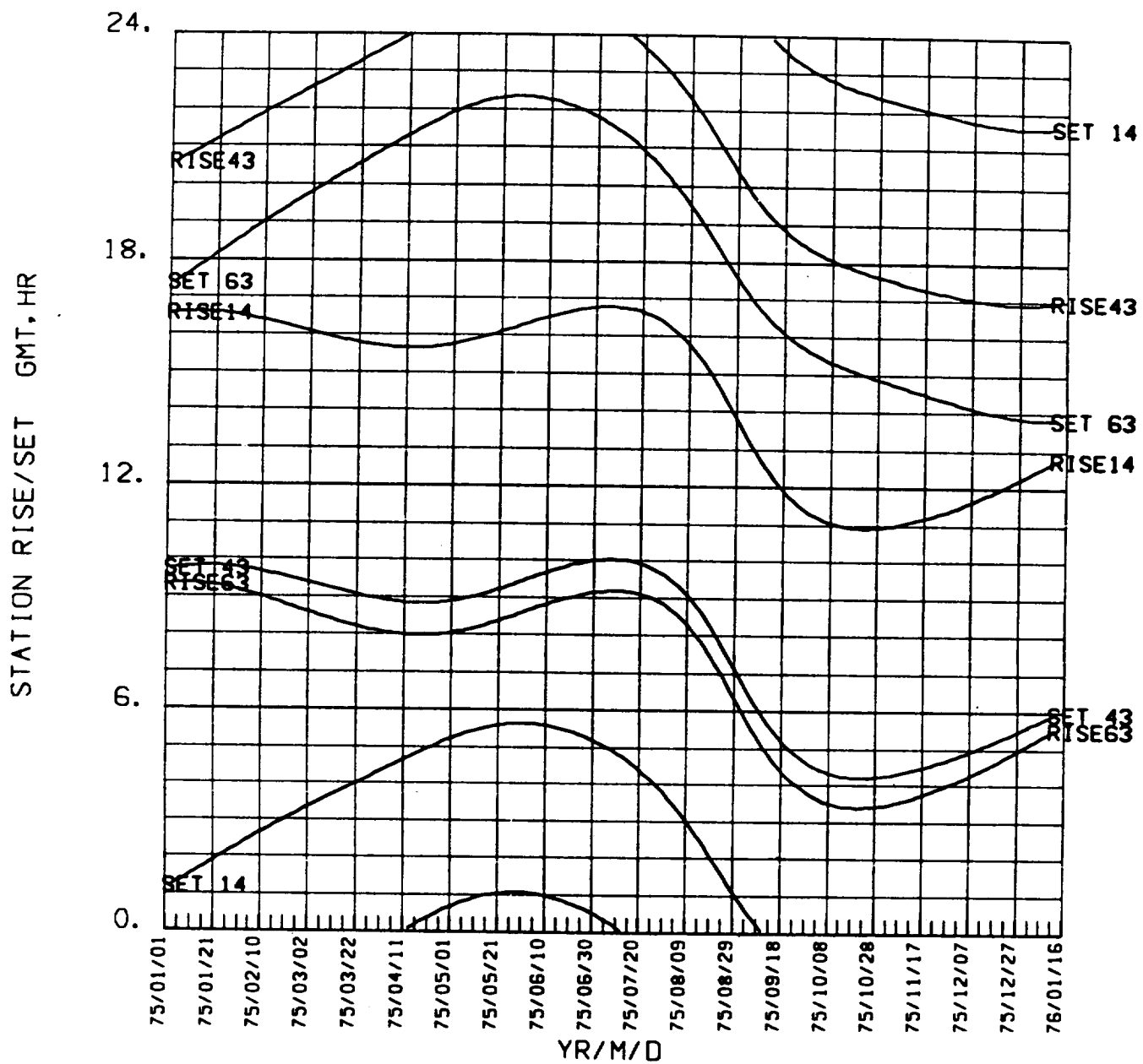
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VENUS 1975

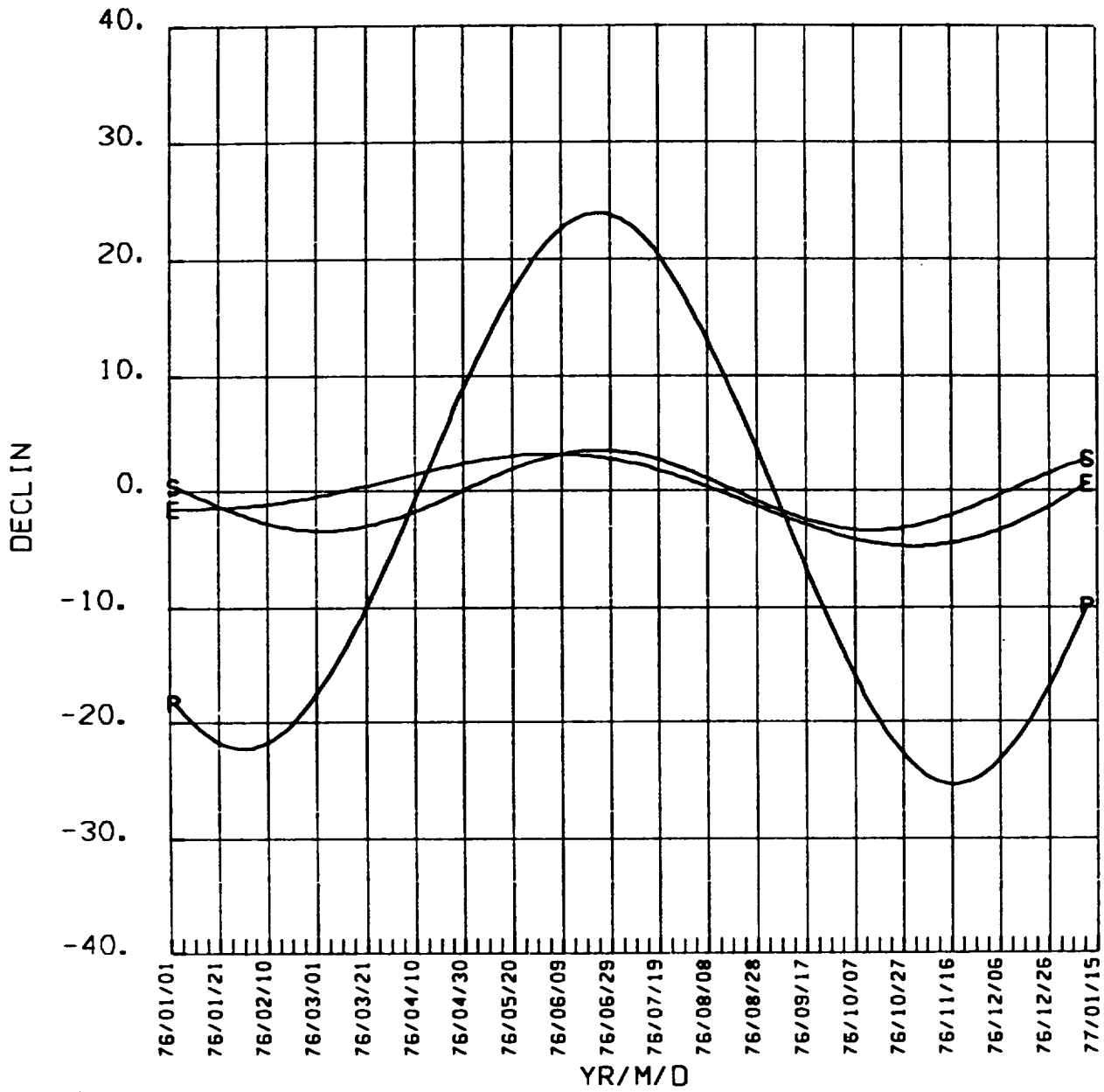


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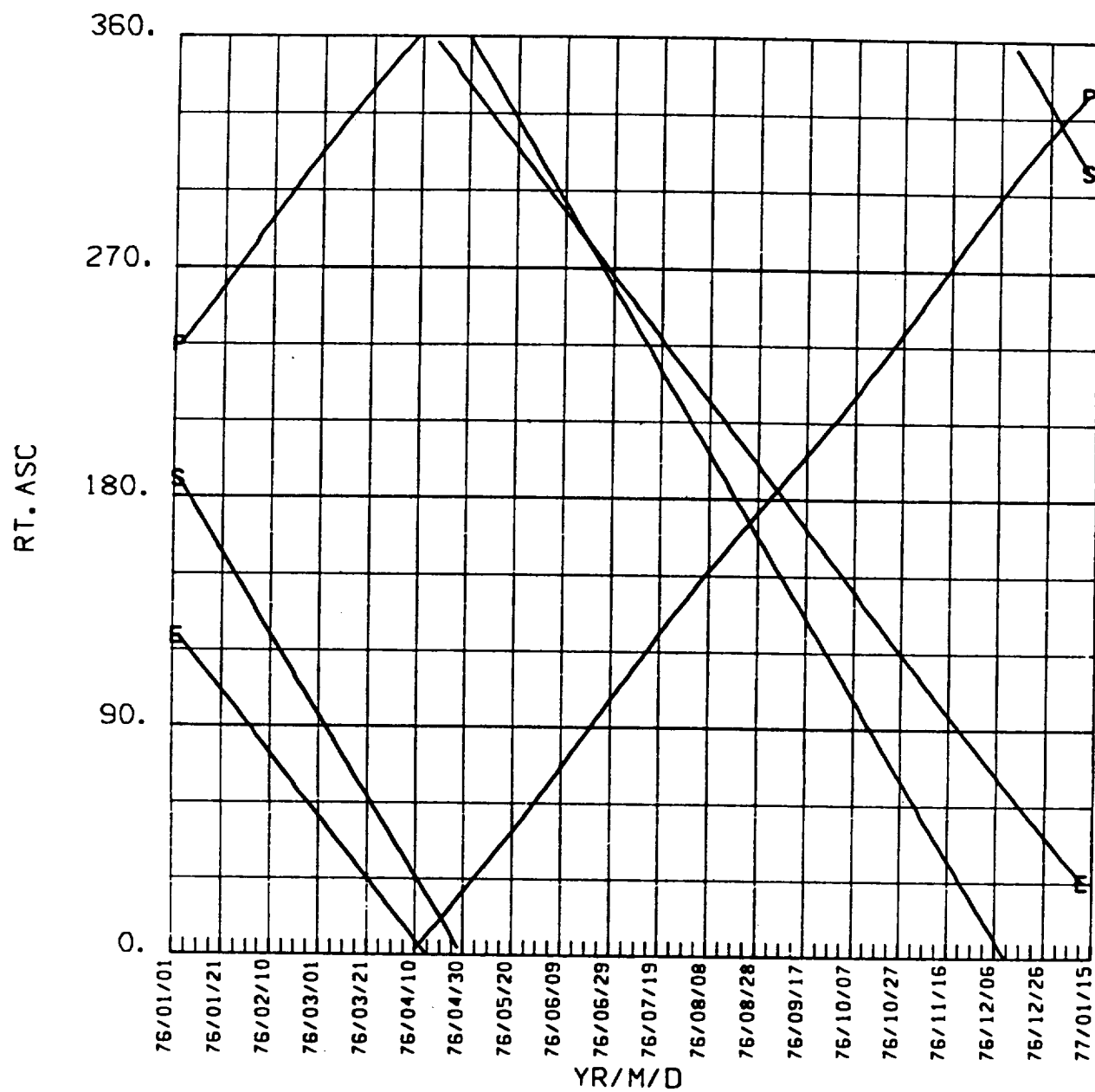
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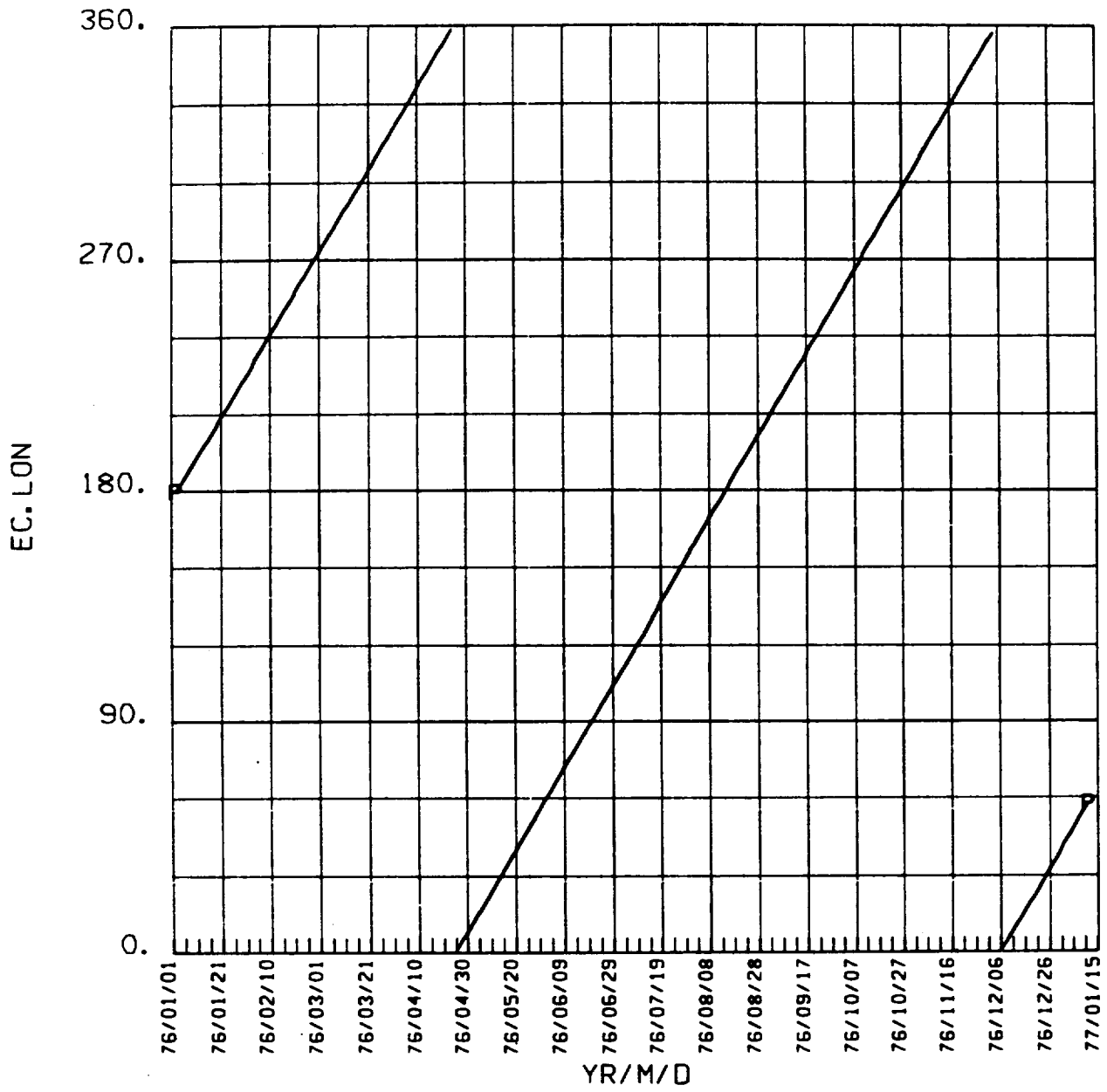
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VENUS

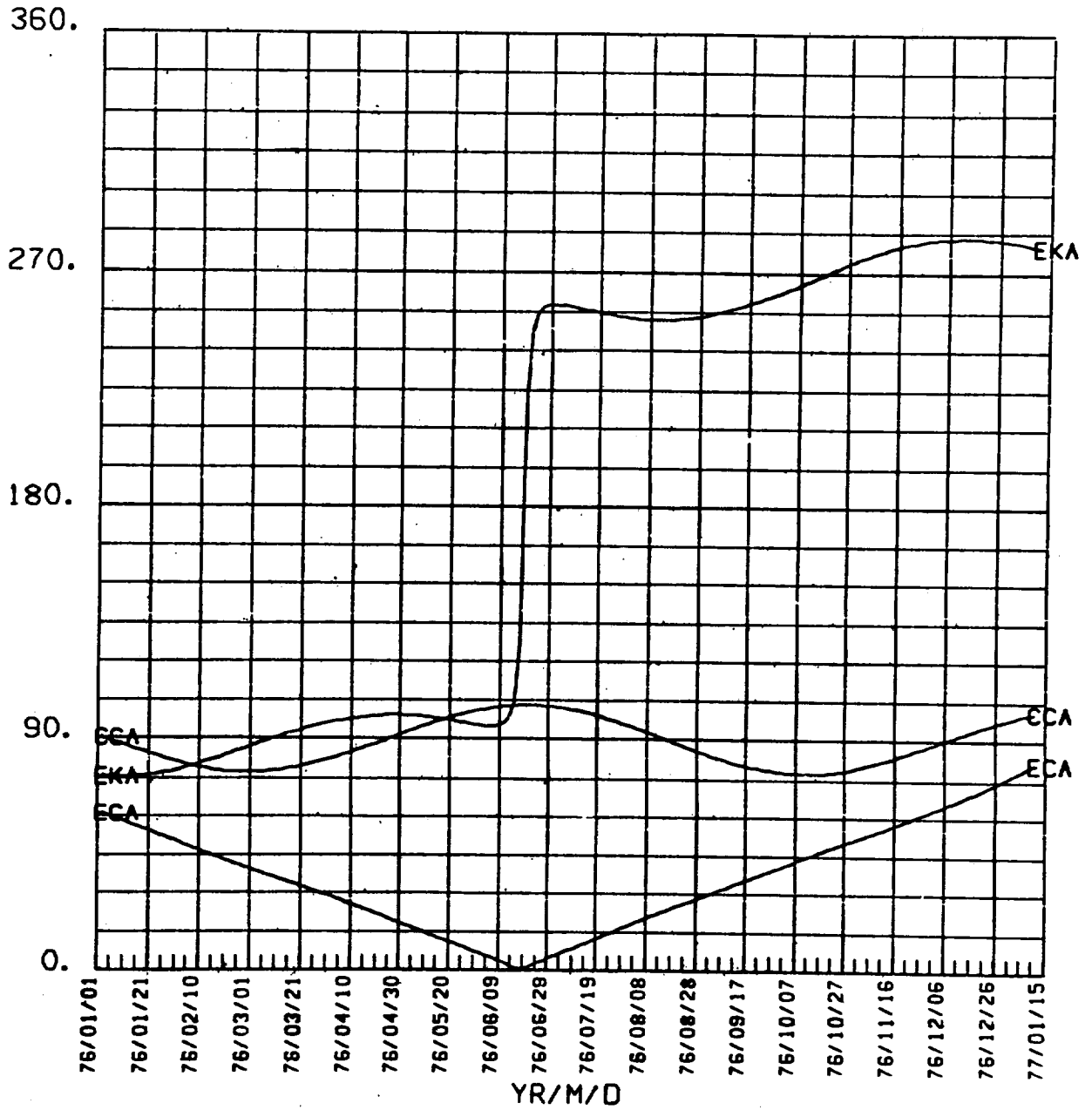
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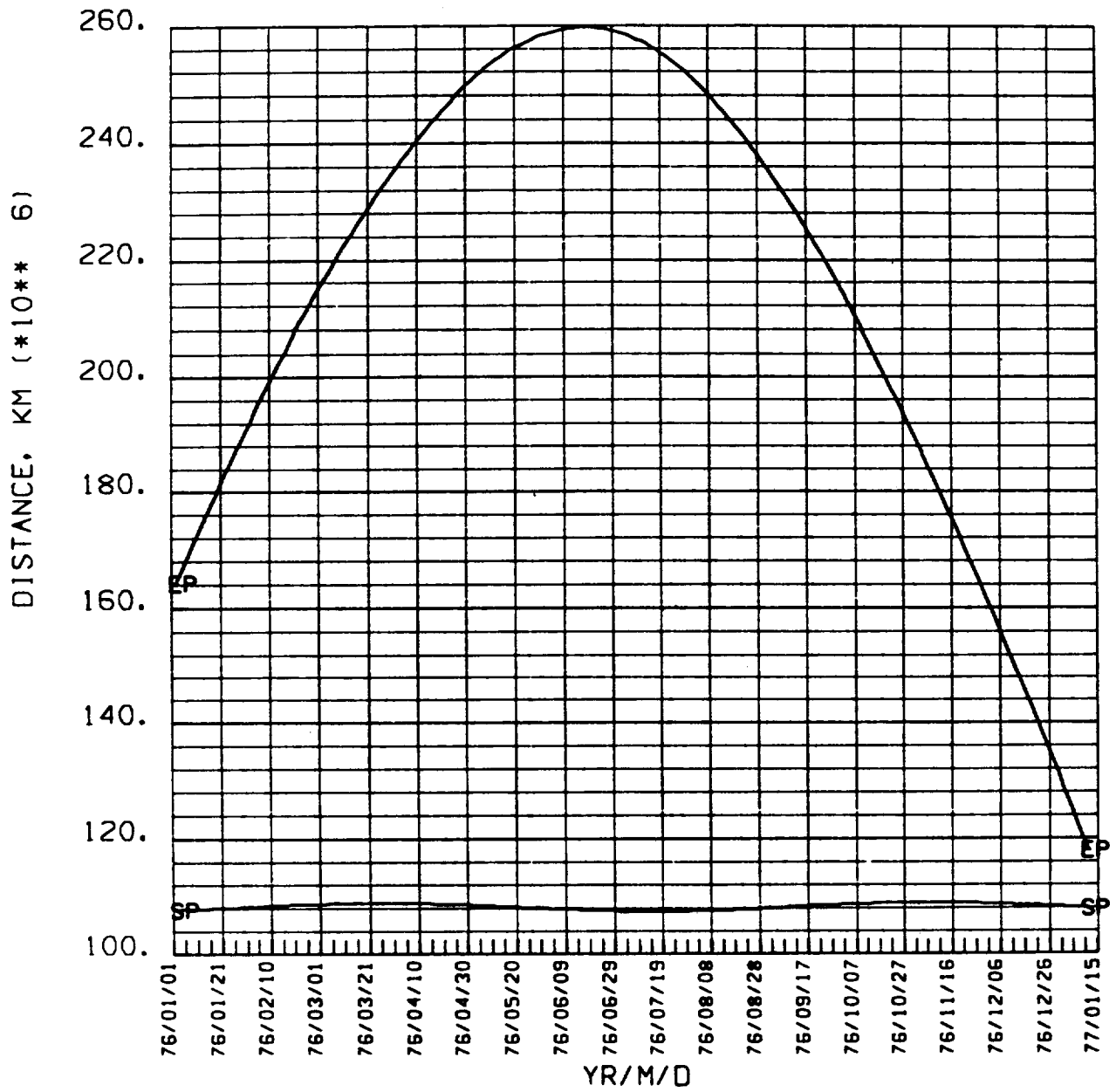
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CA-KA OF EARTH, CA CANOP



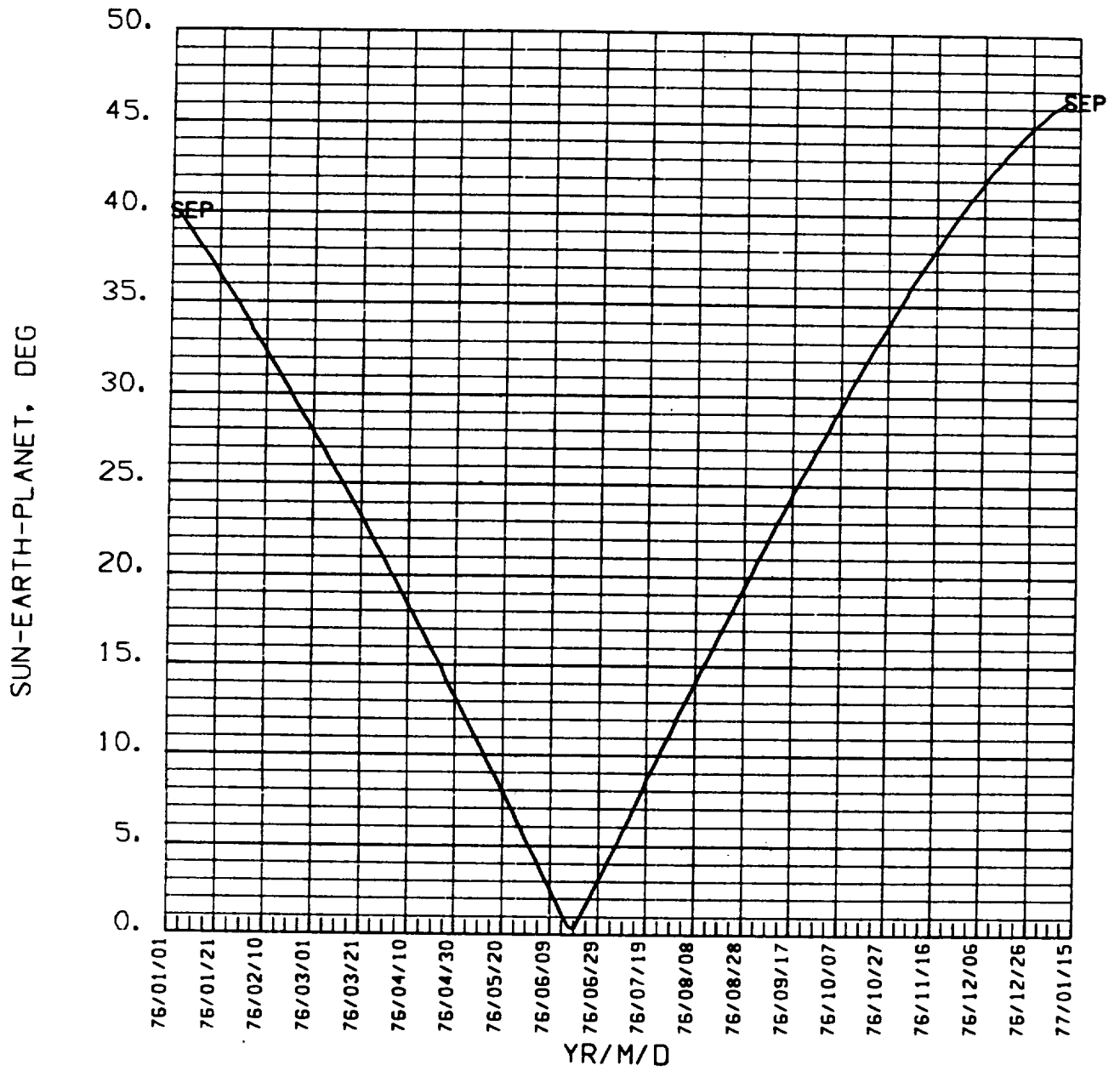
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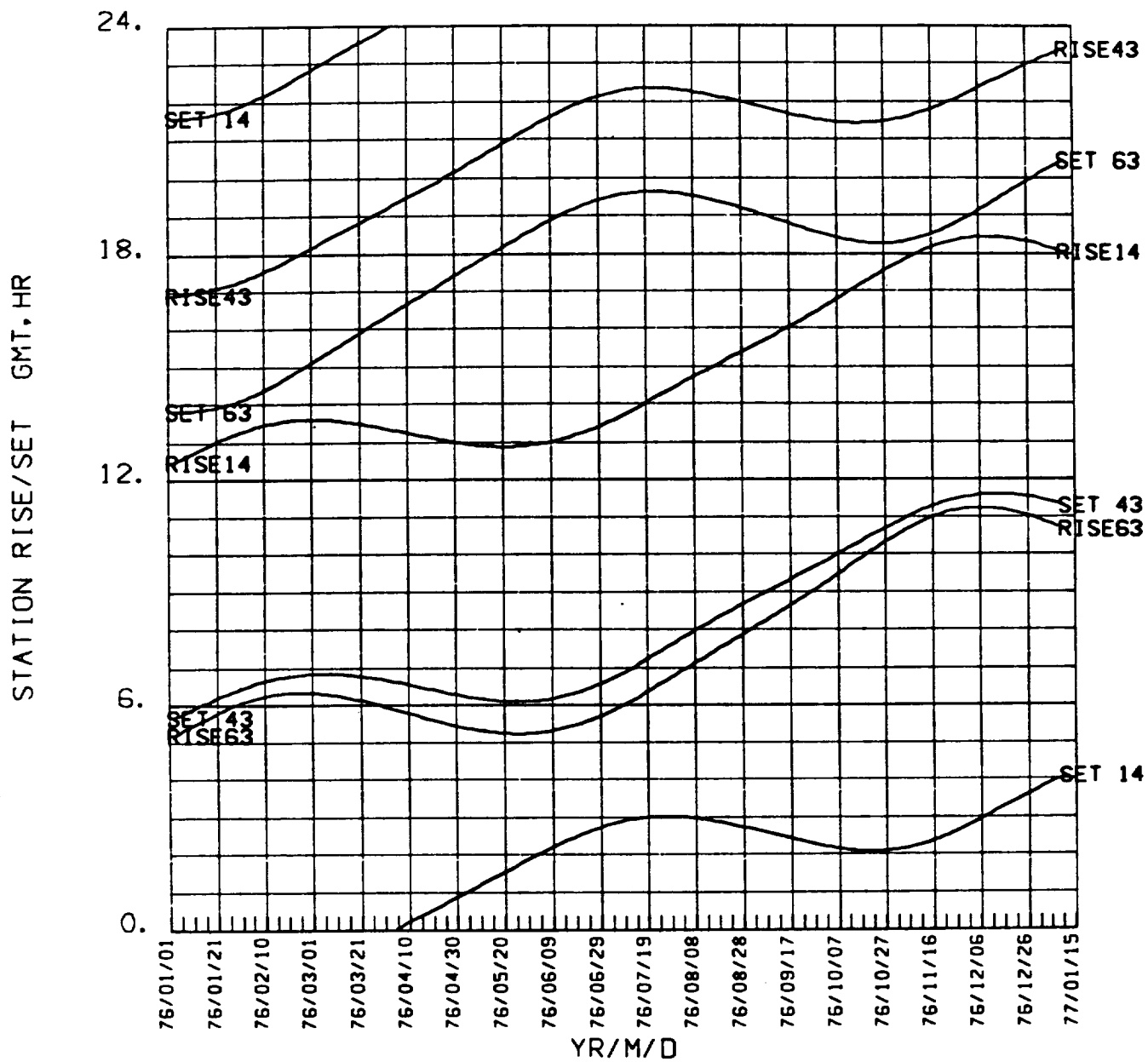


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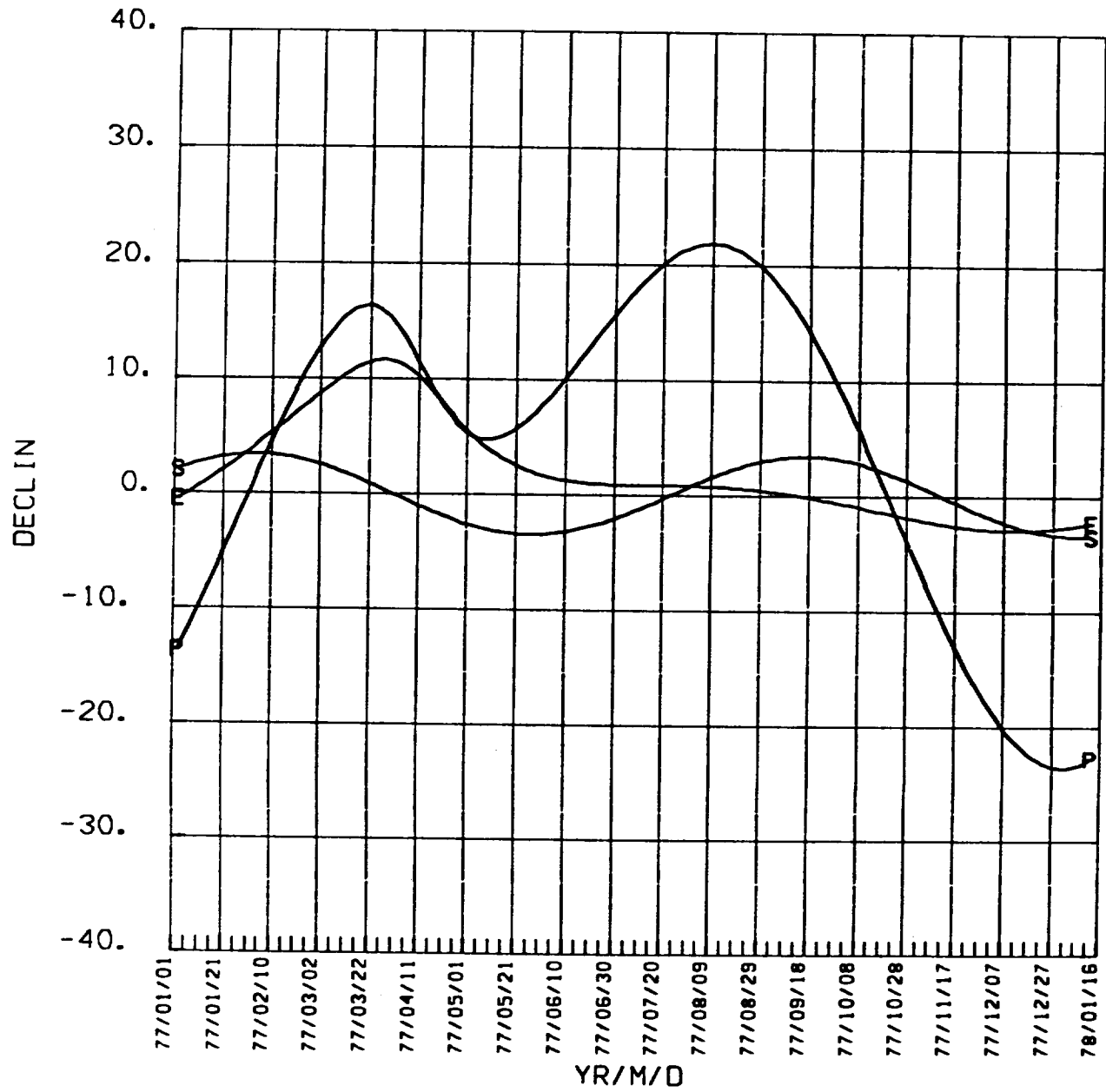


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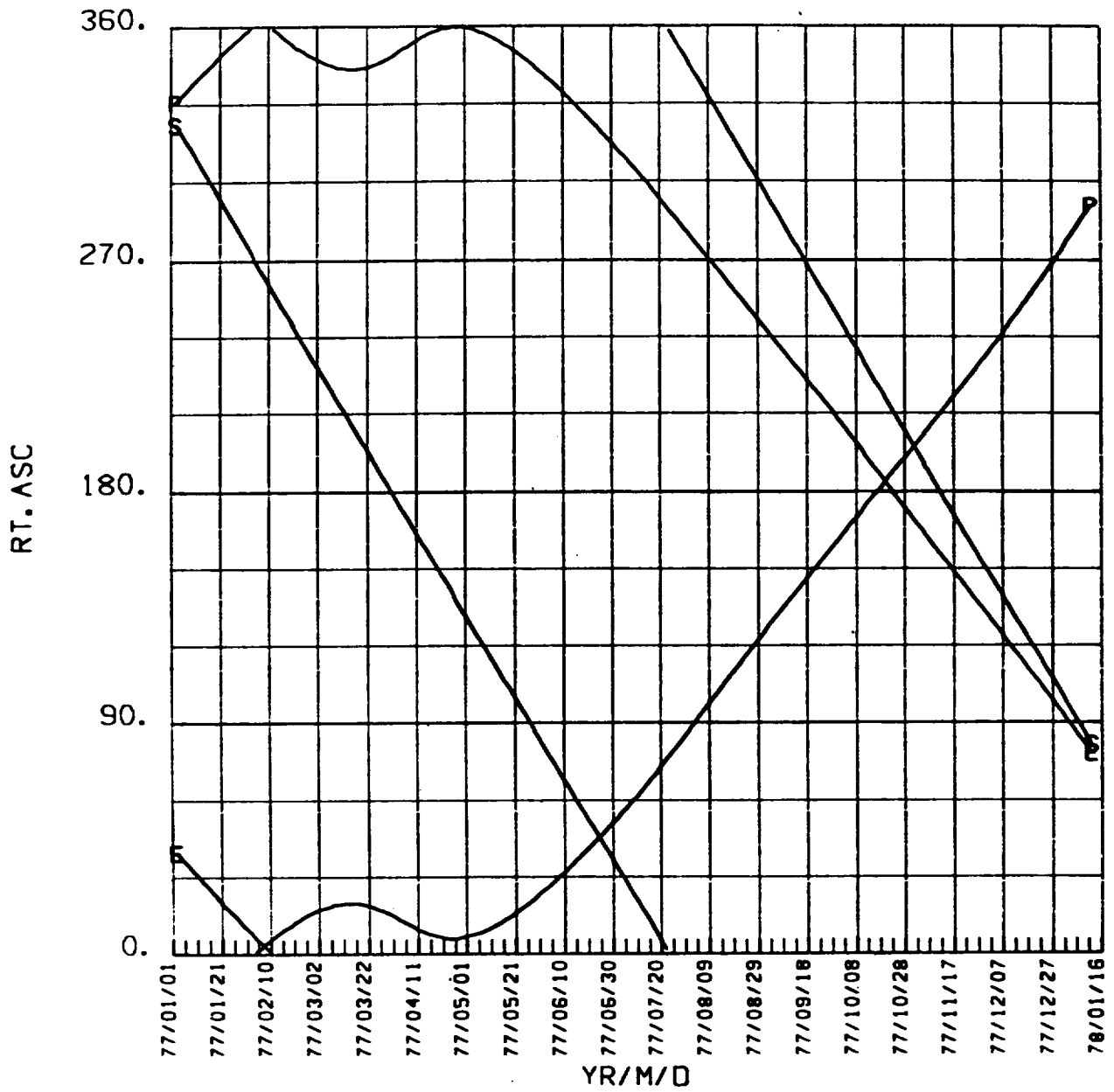
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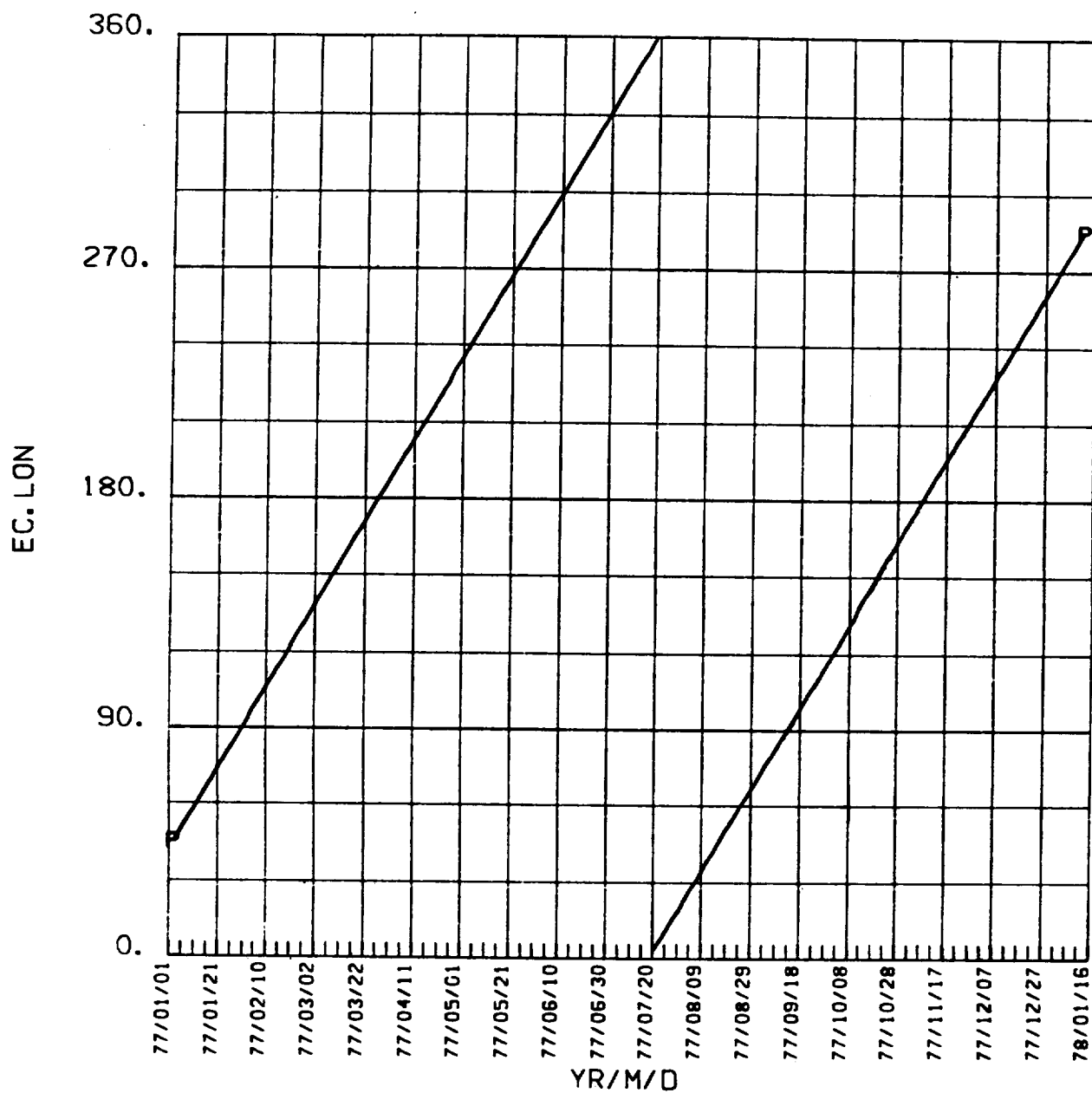


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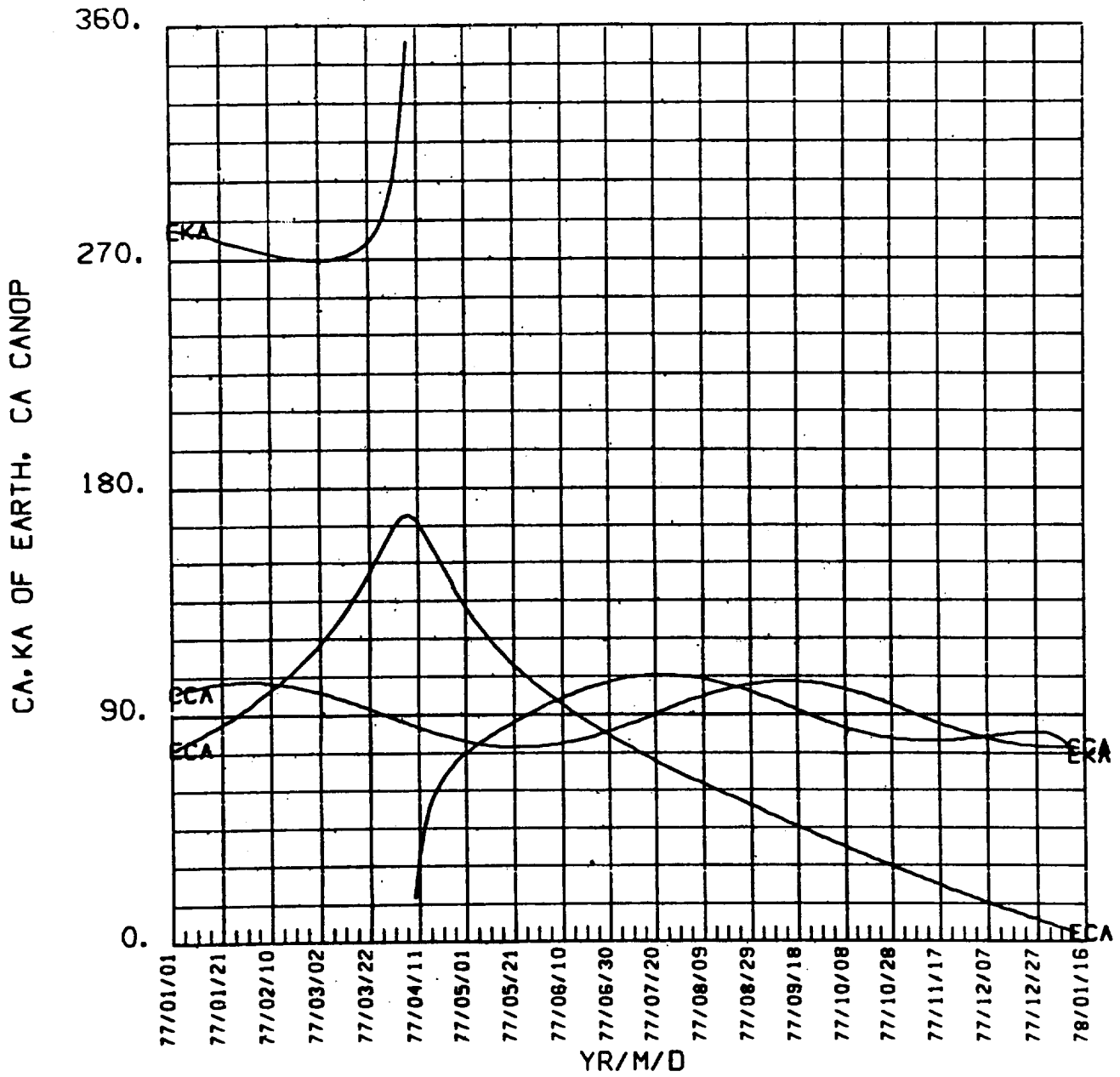


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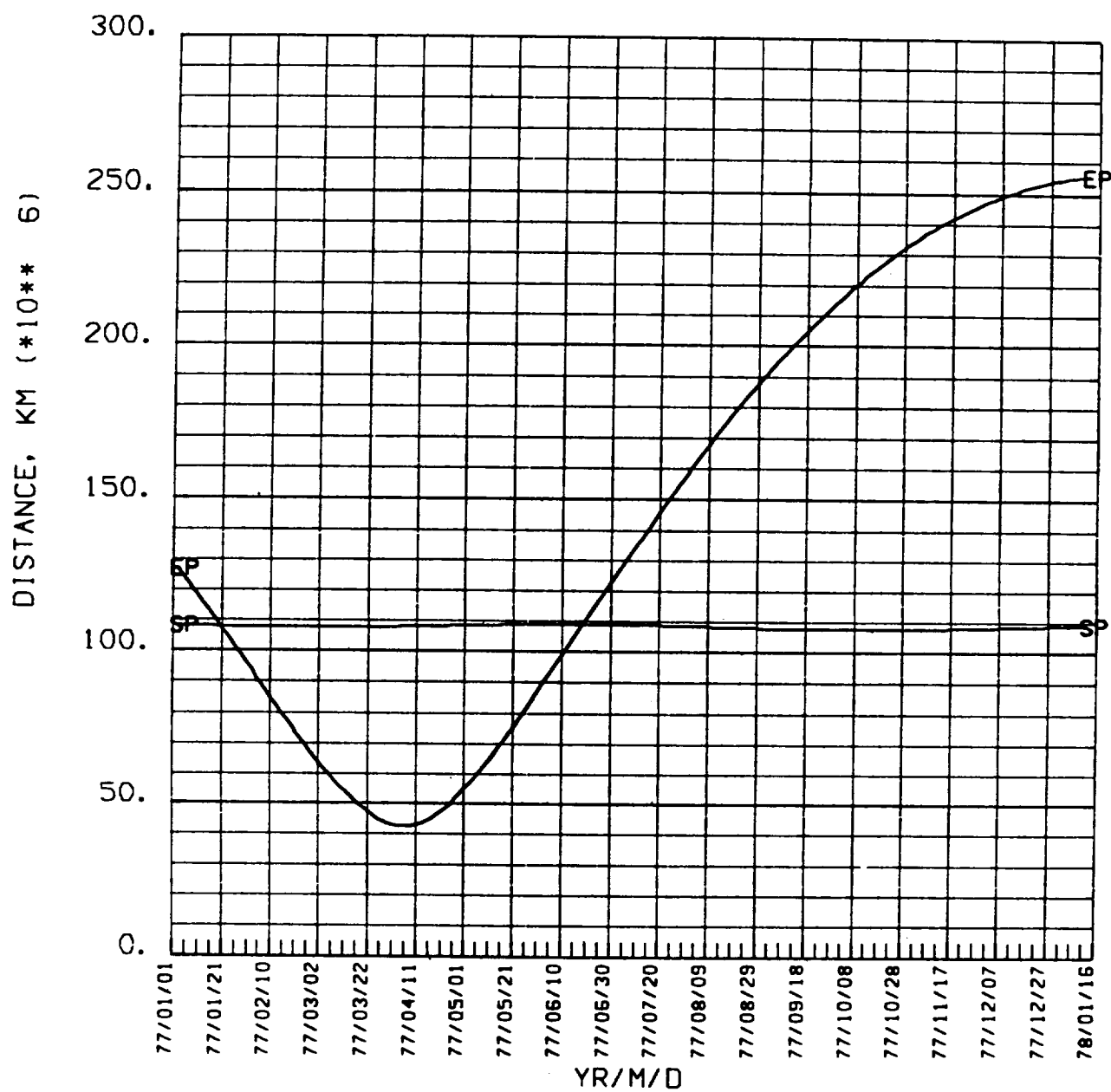
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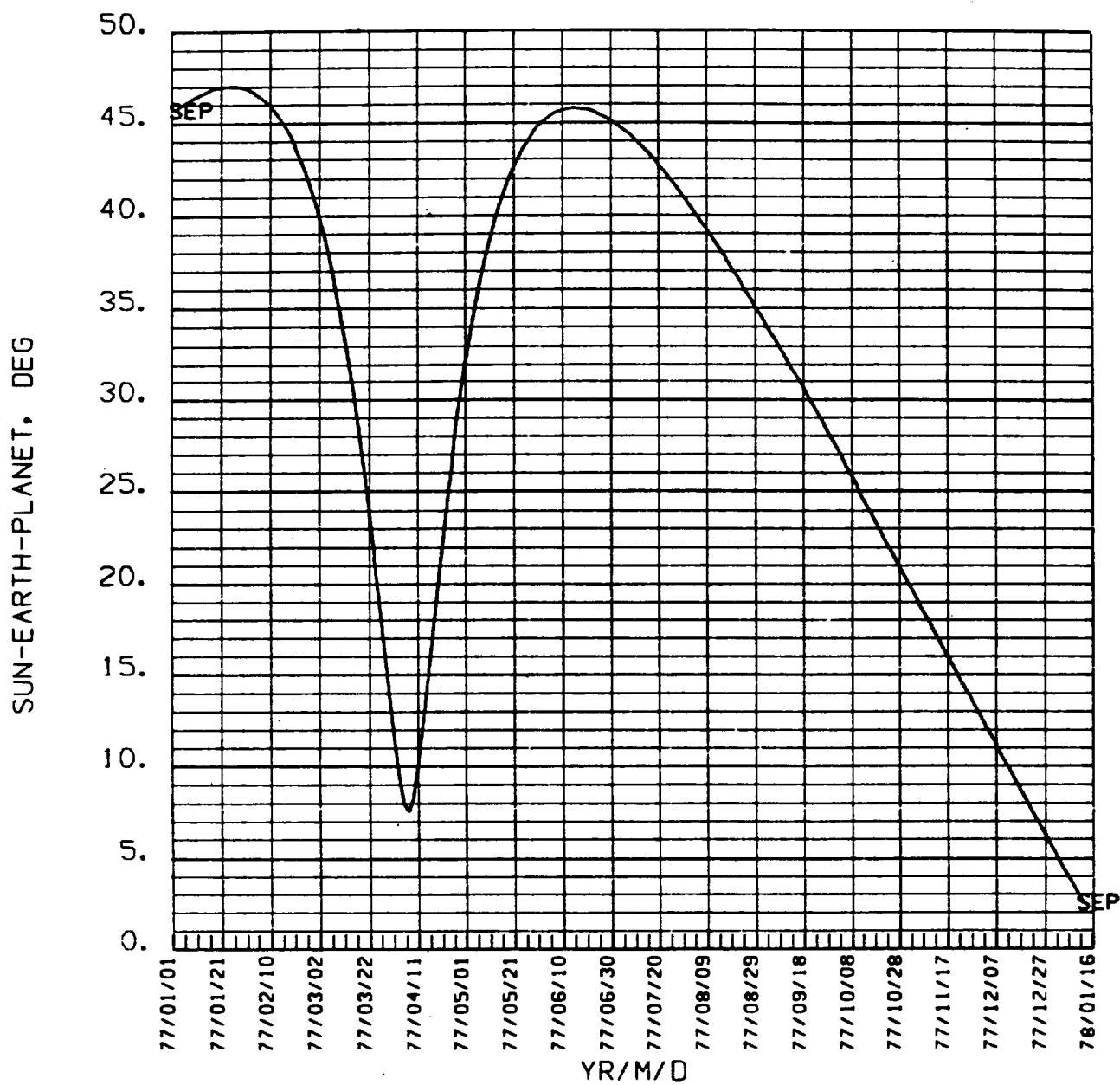


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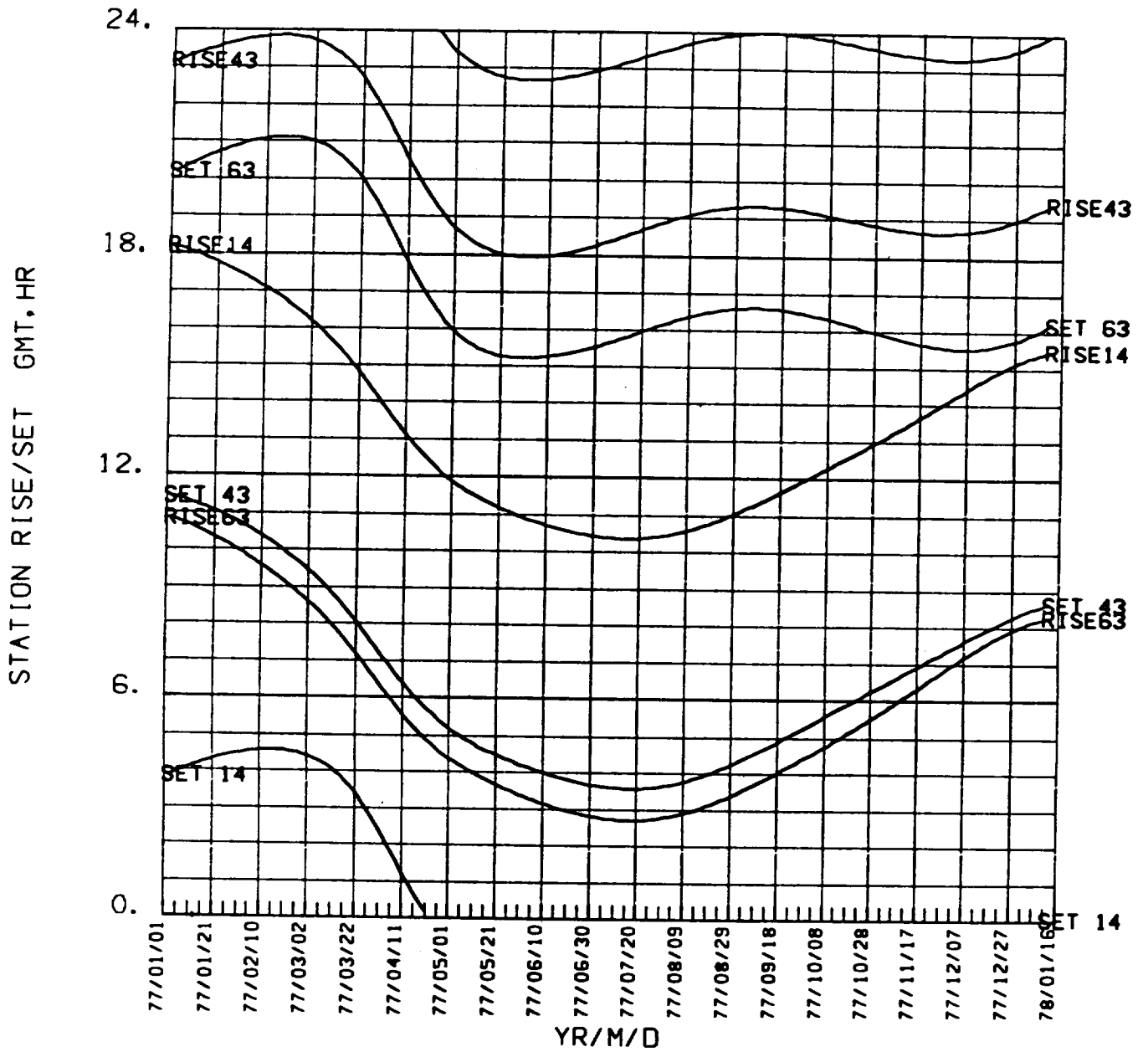


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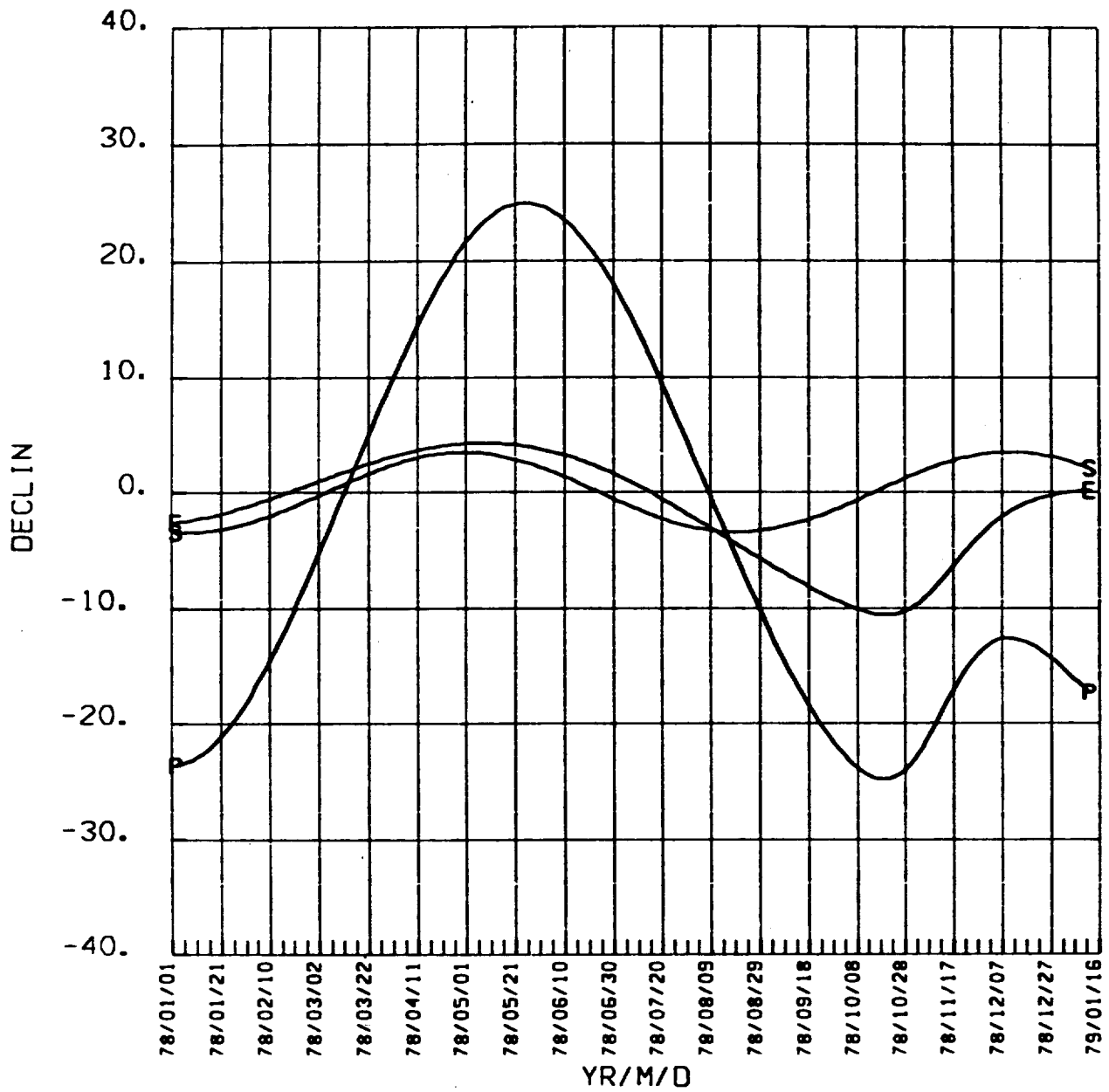
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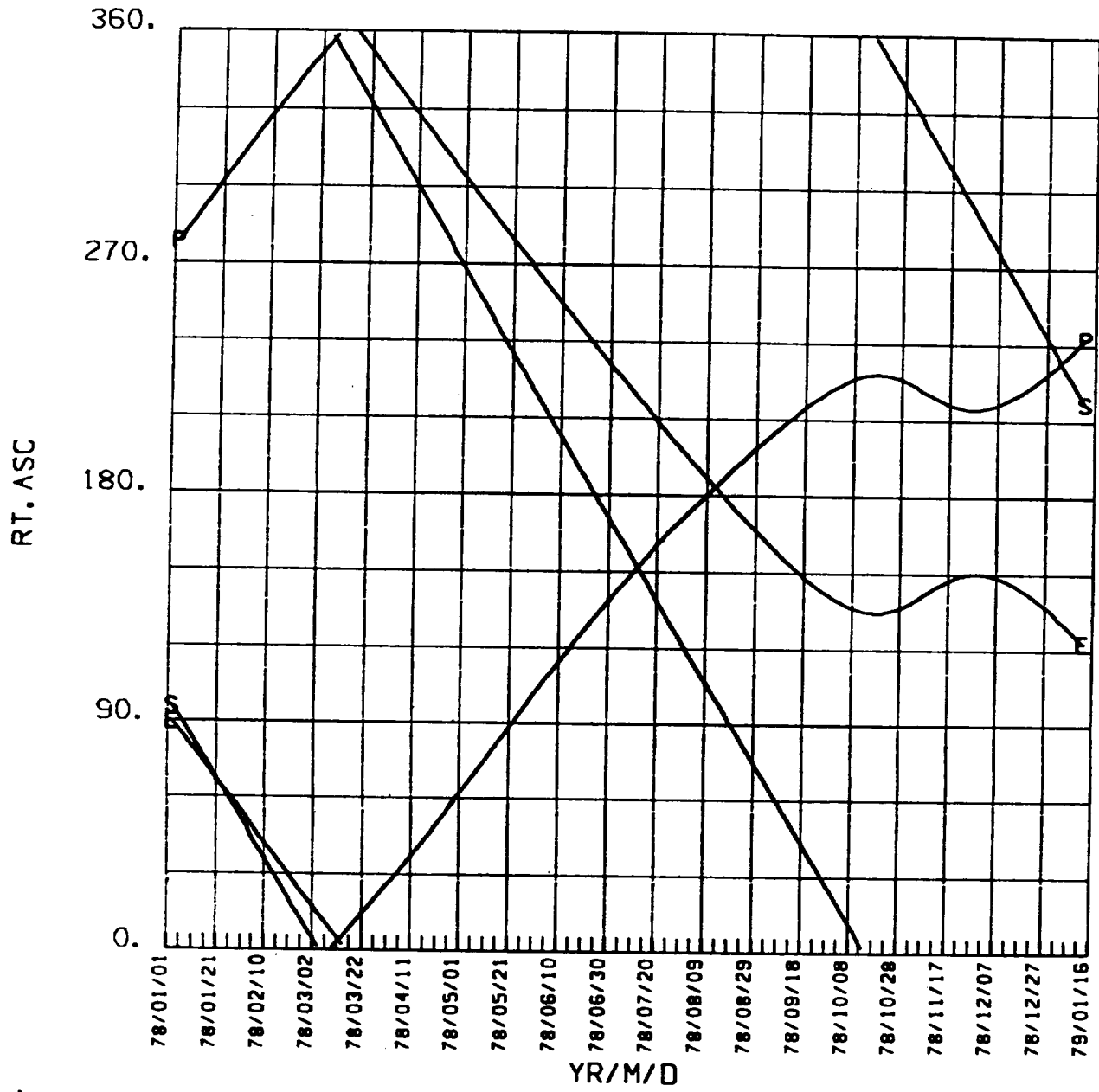
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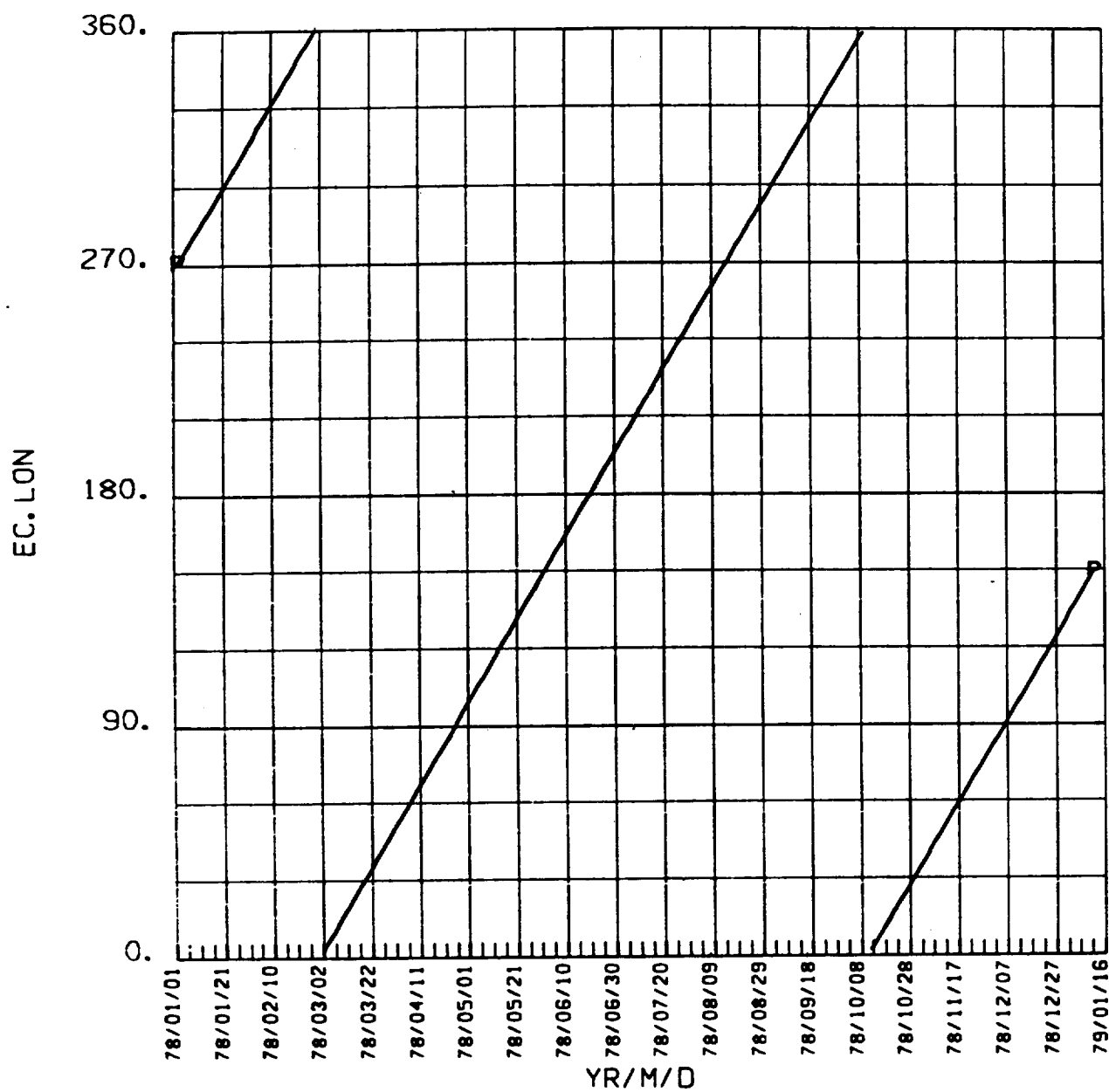
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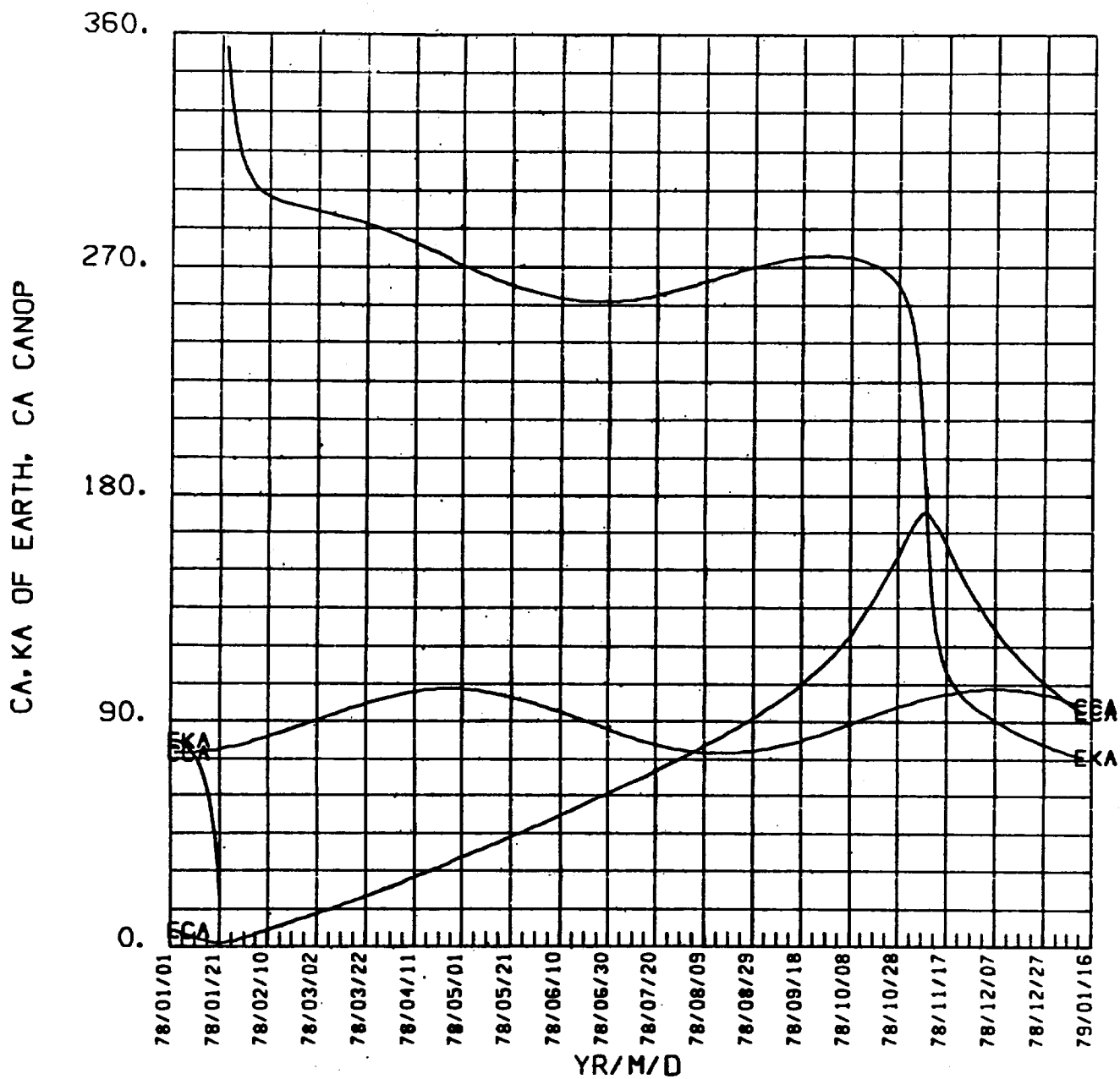
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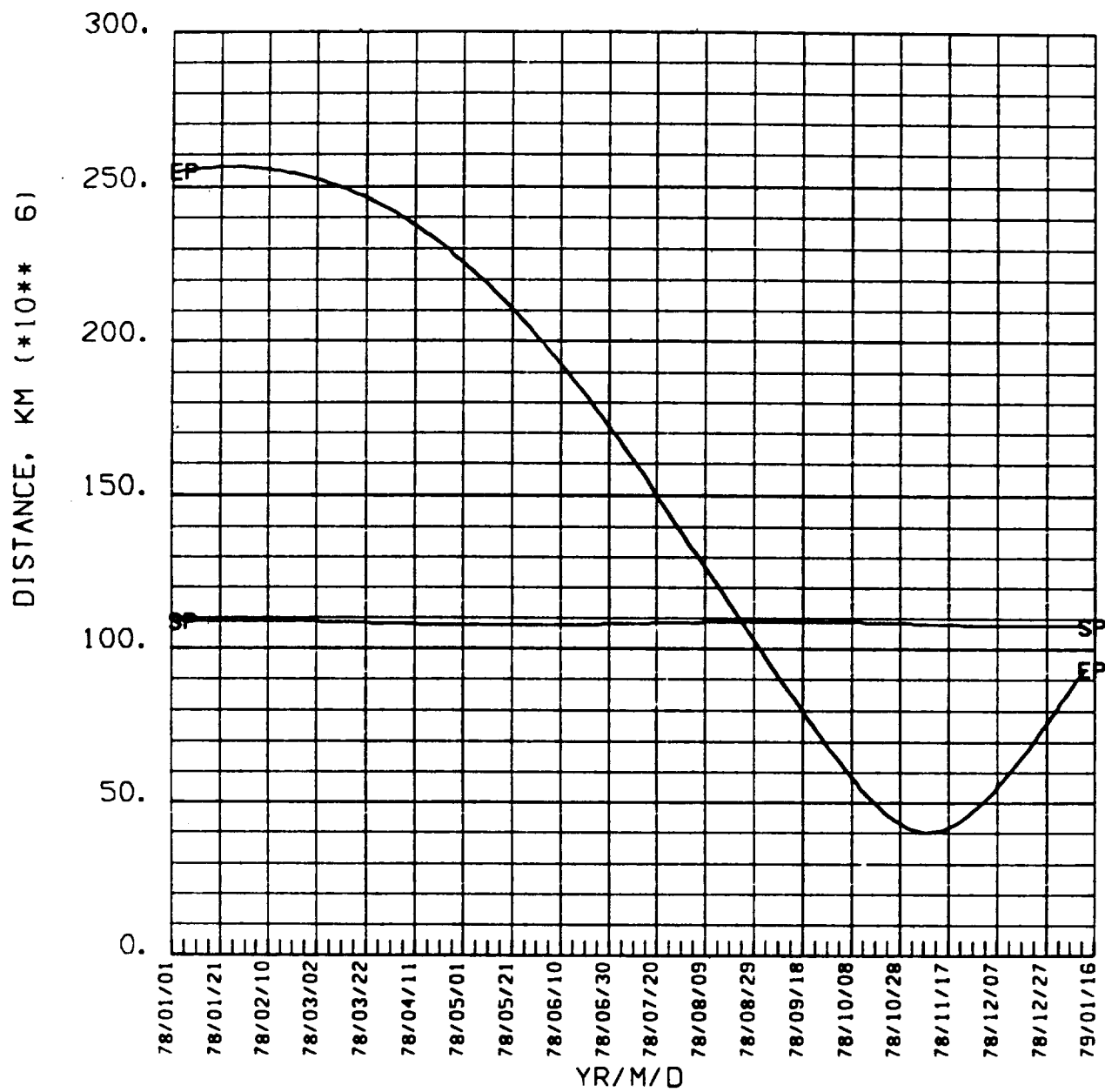
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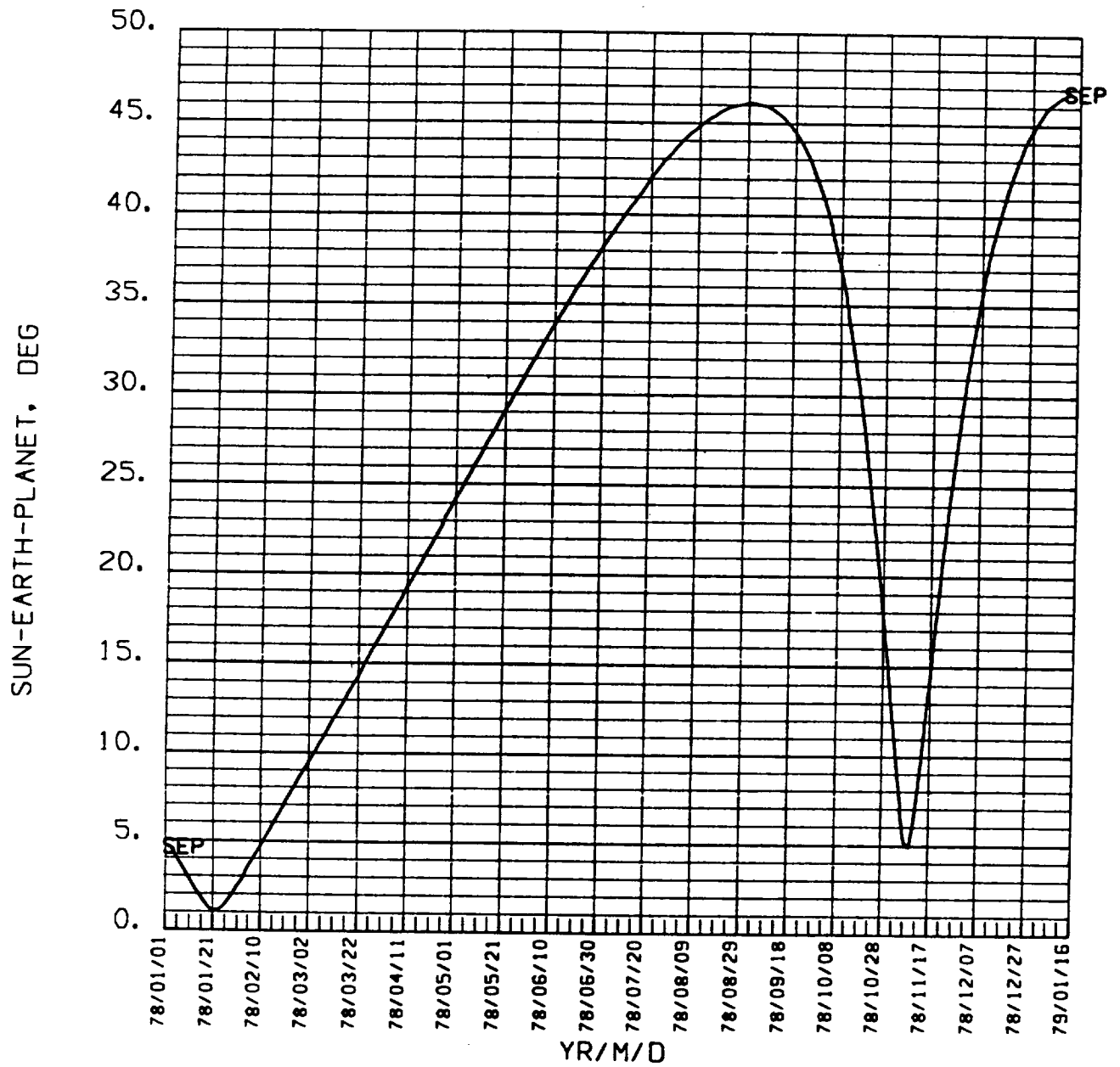
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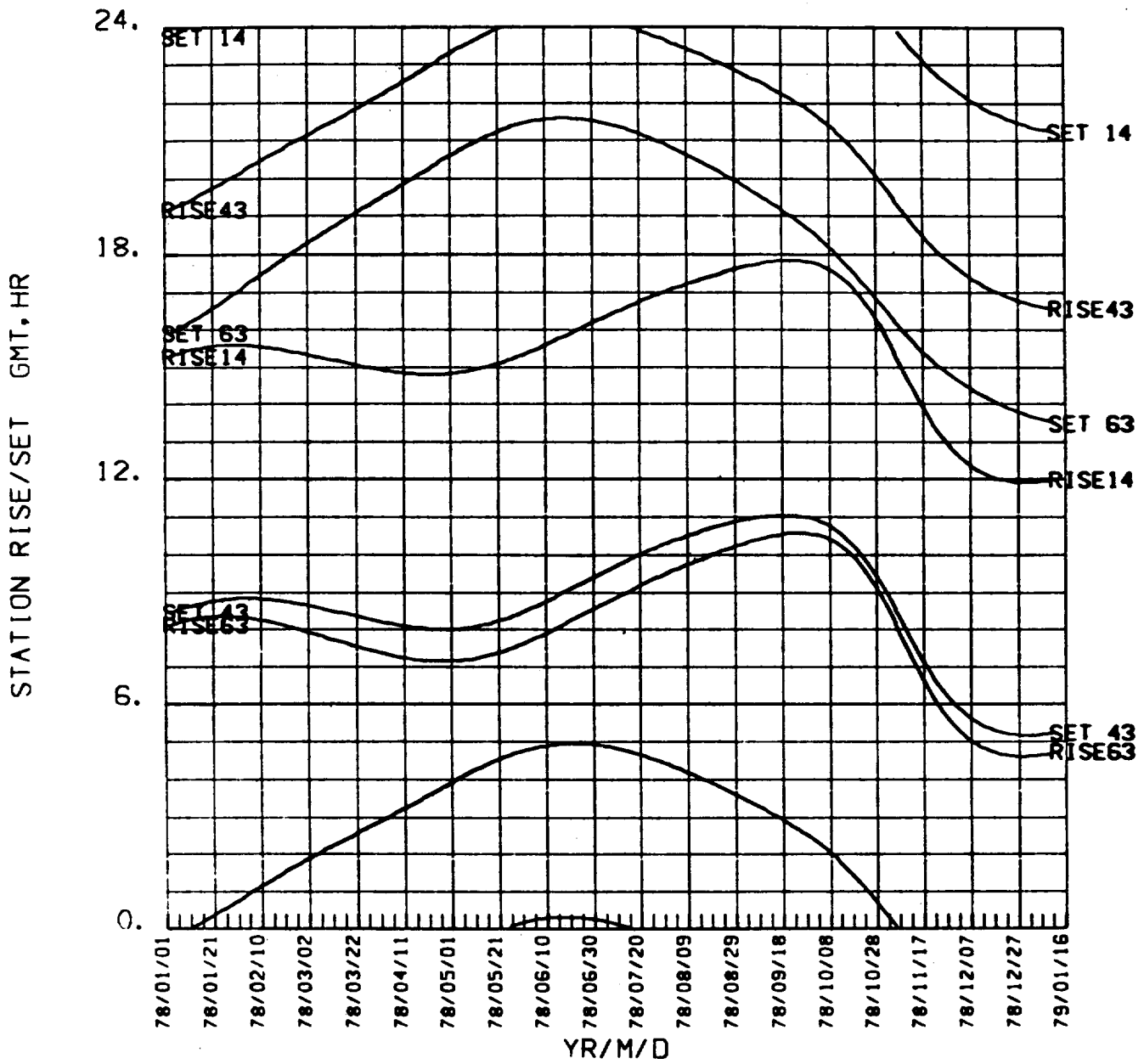


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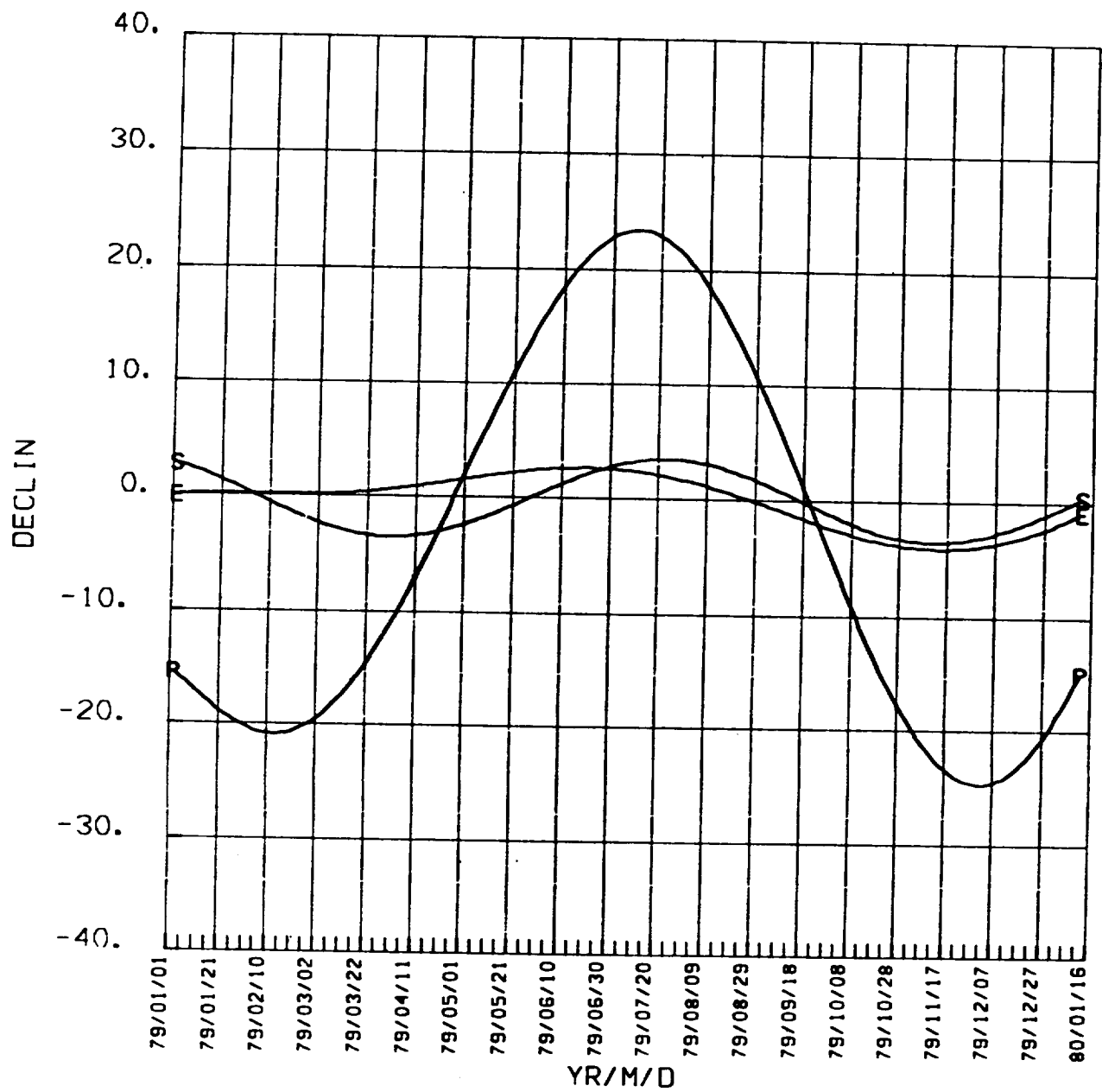
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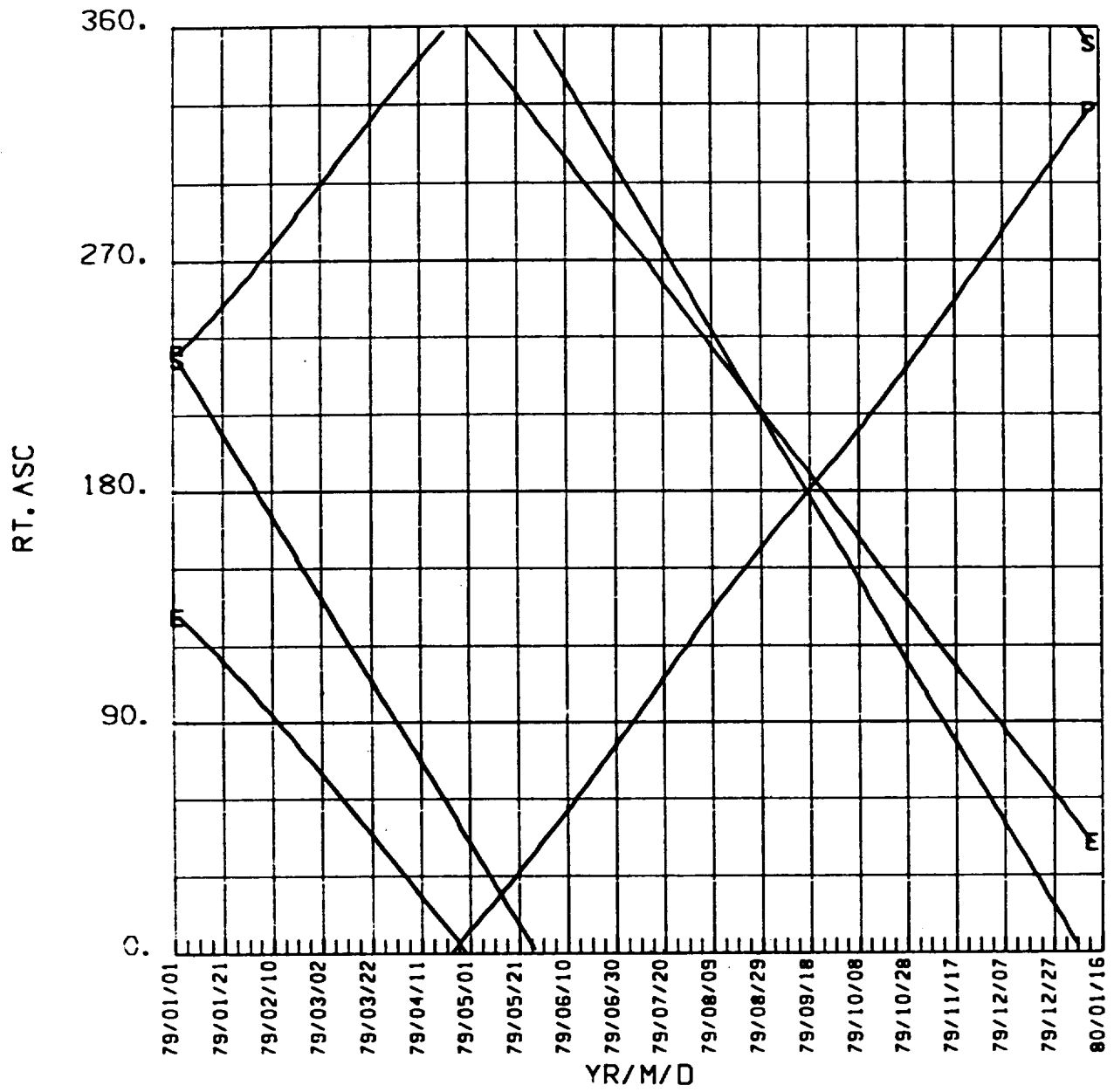


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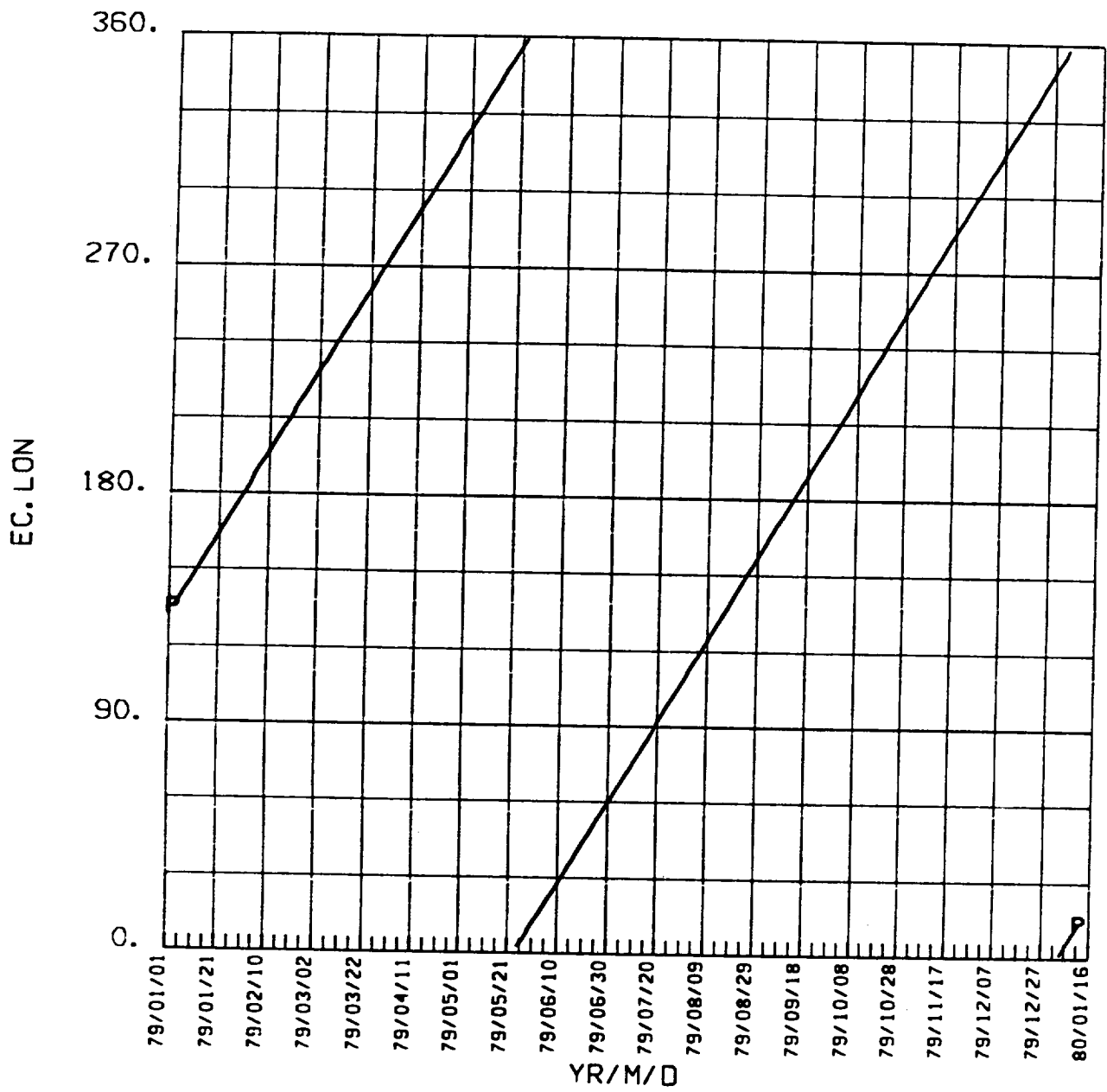


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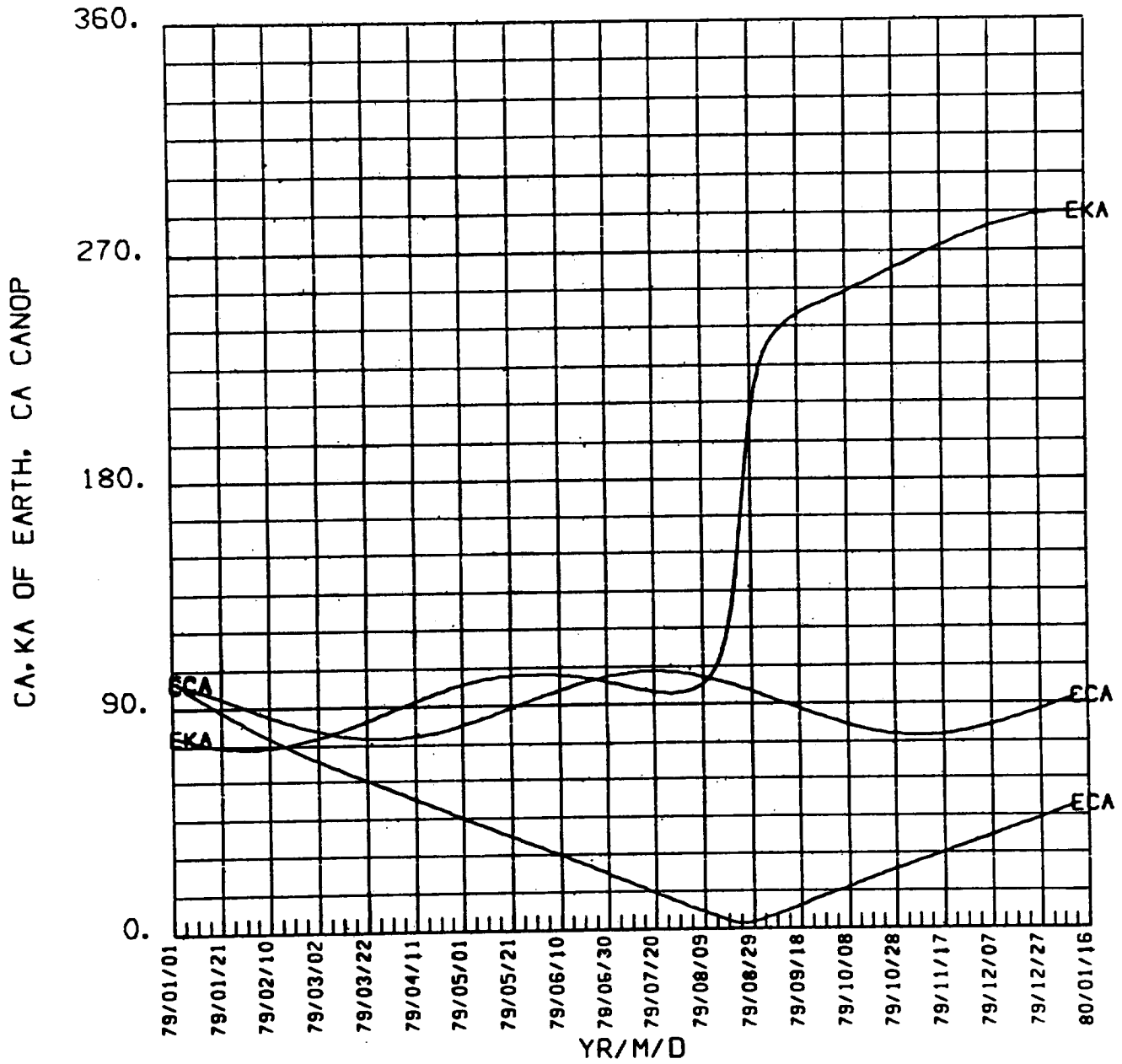


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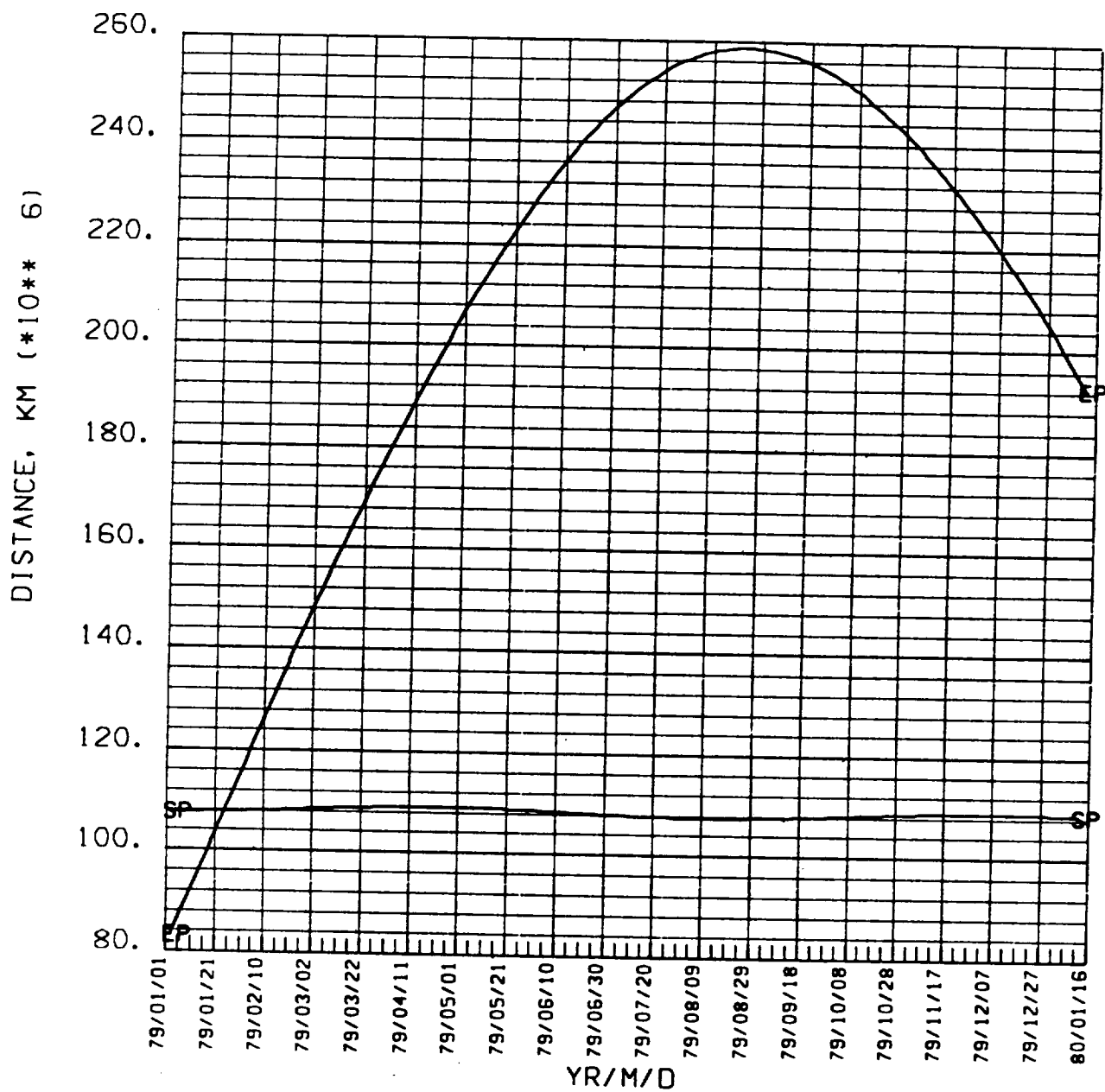
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VENUS

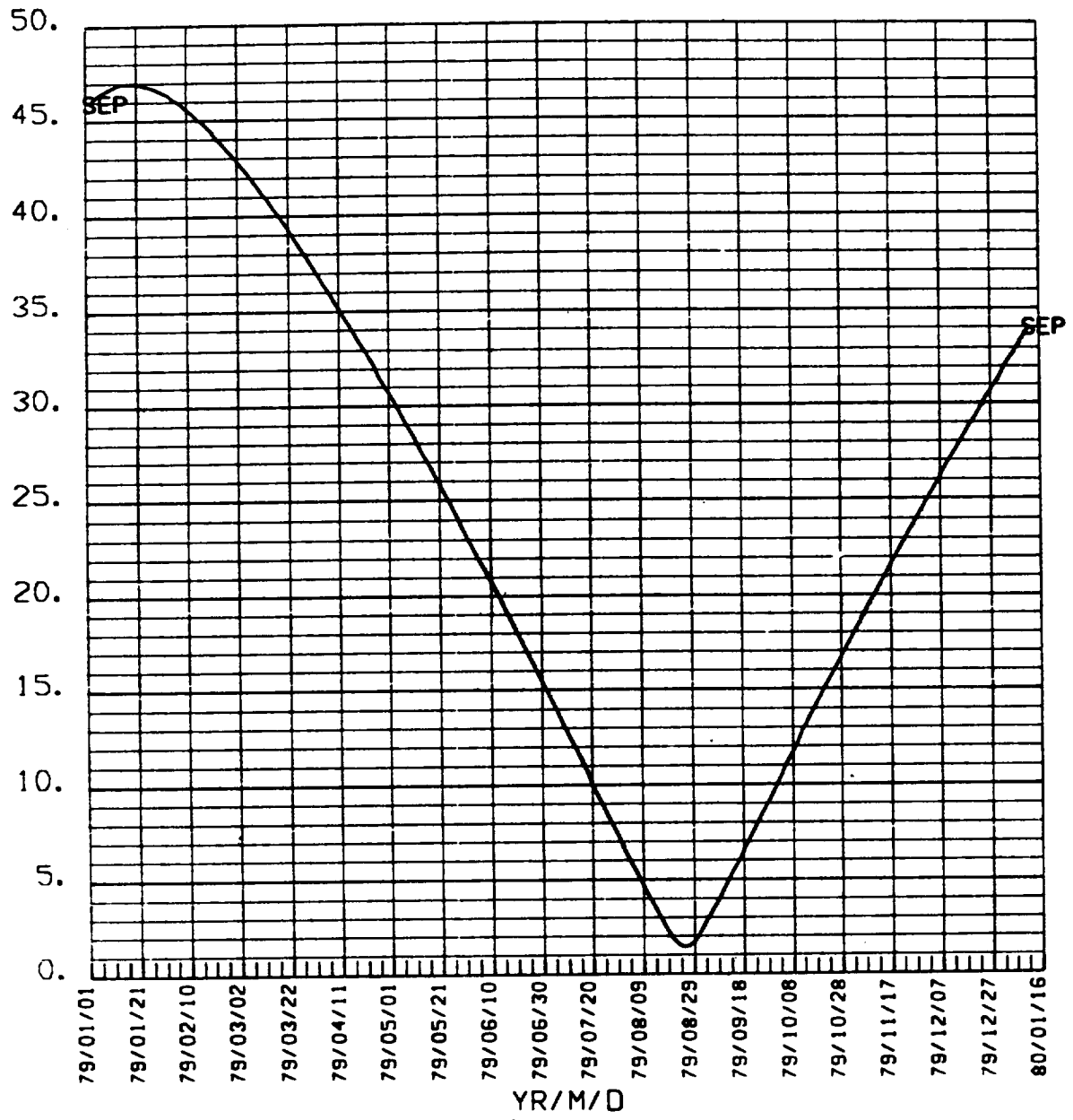
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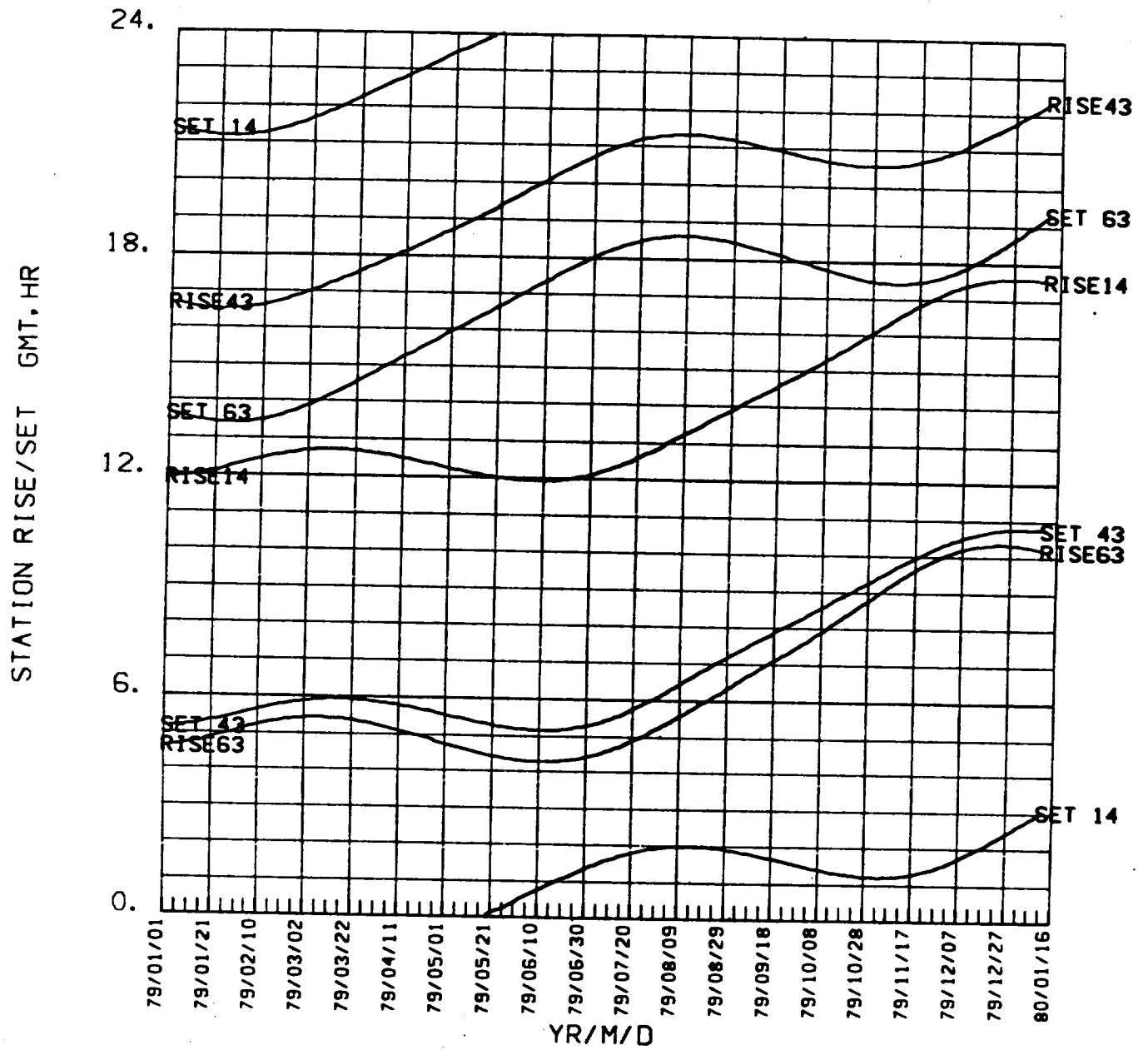
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SUN-EARTH-PLANET, DEG

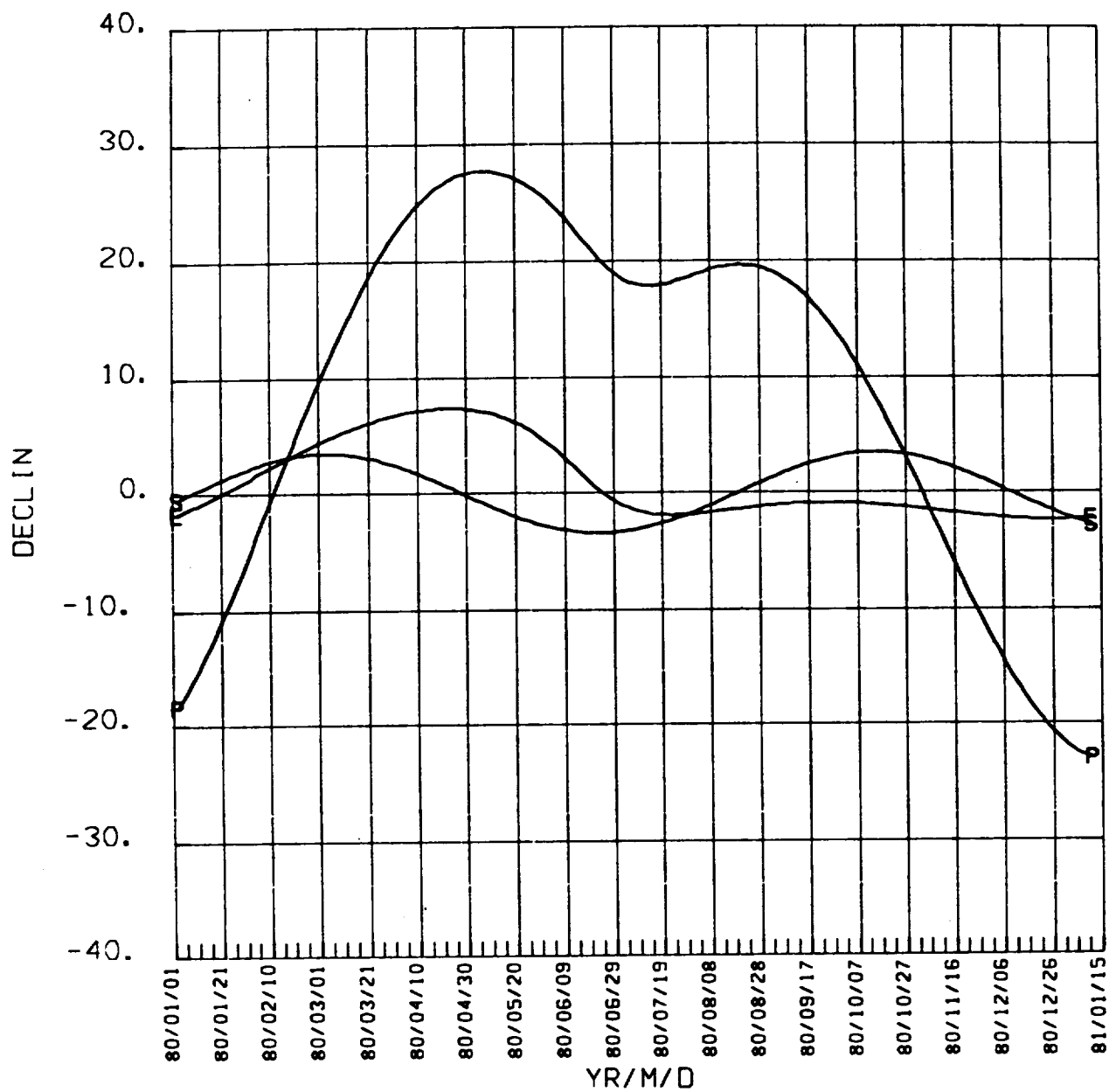


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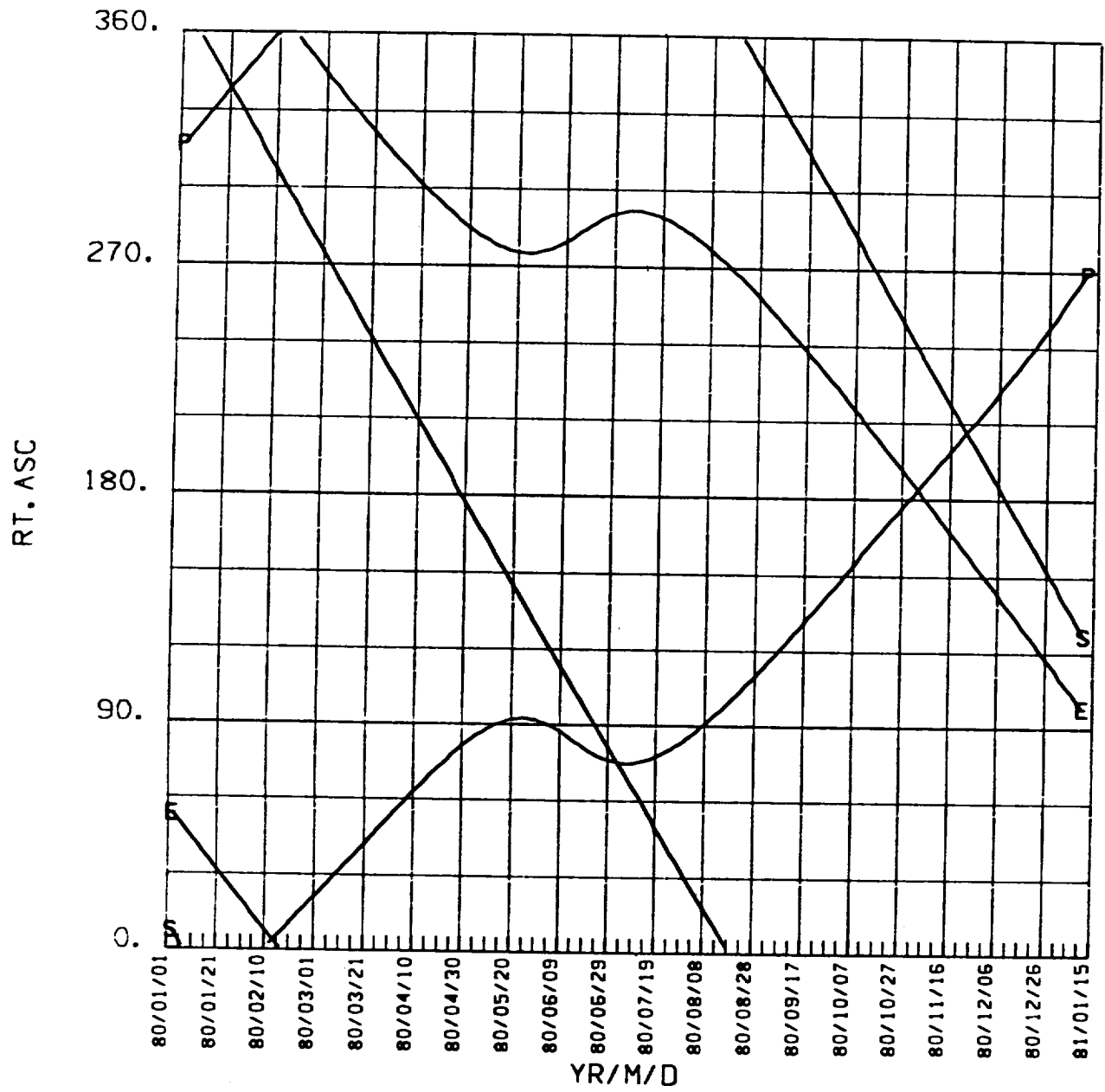


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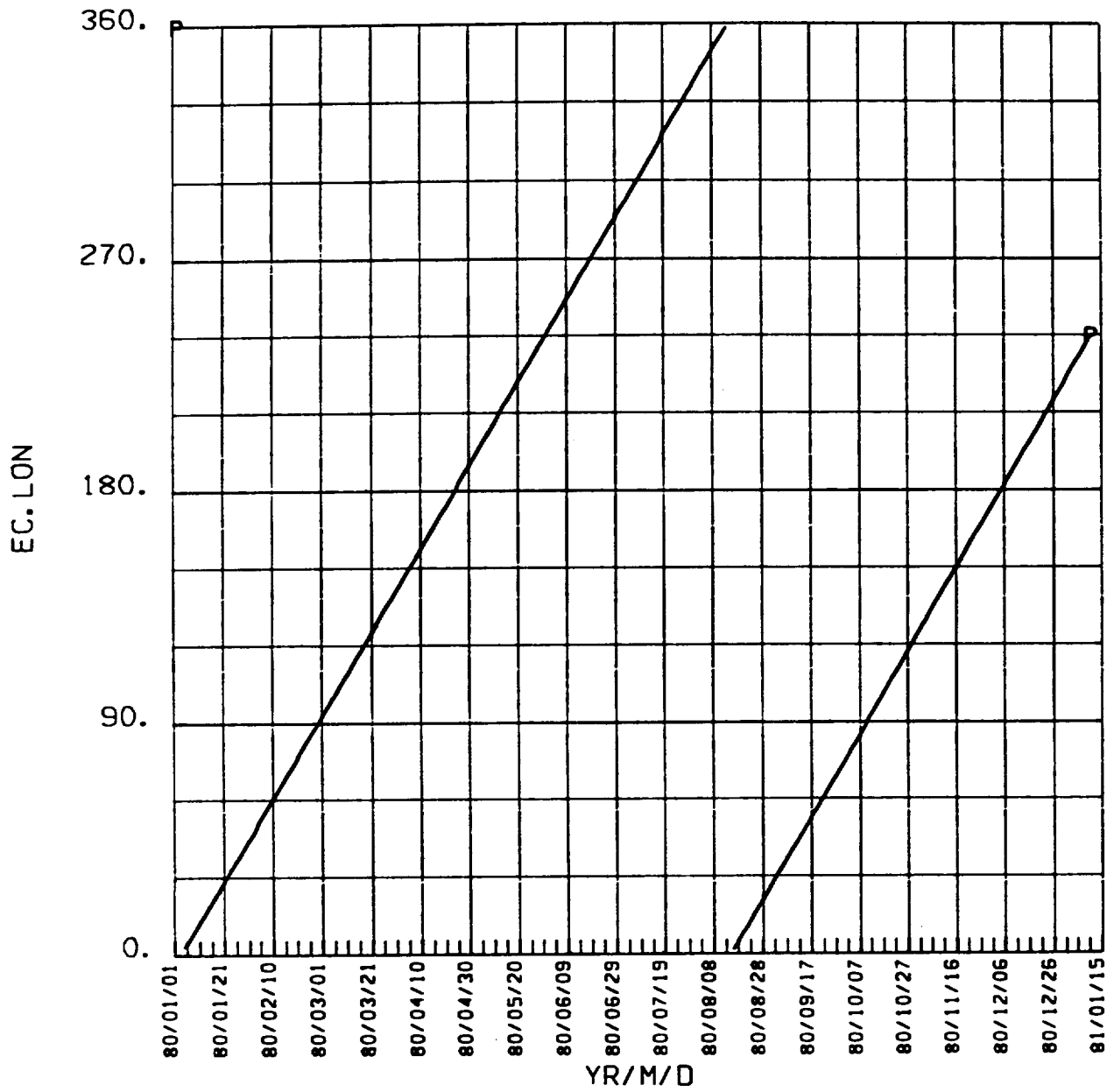
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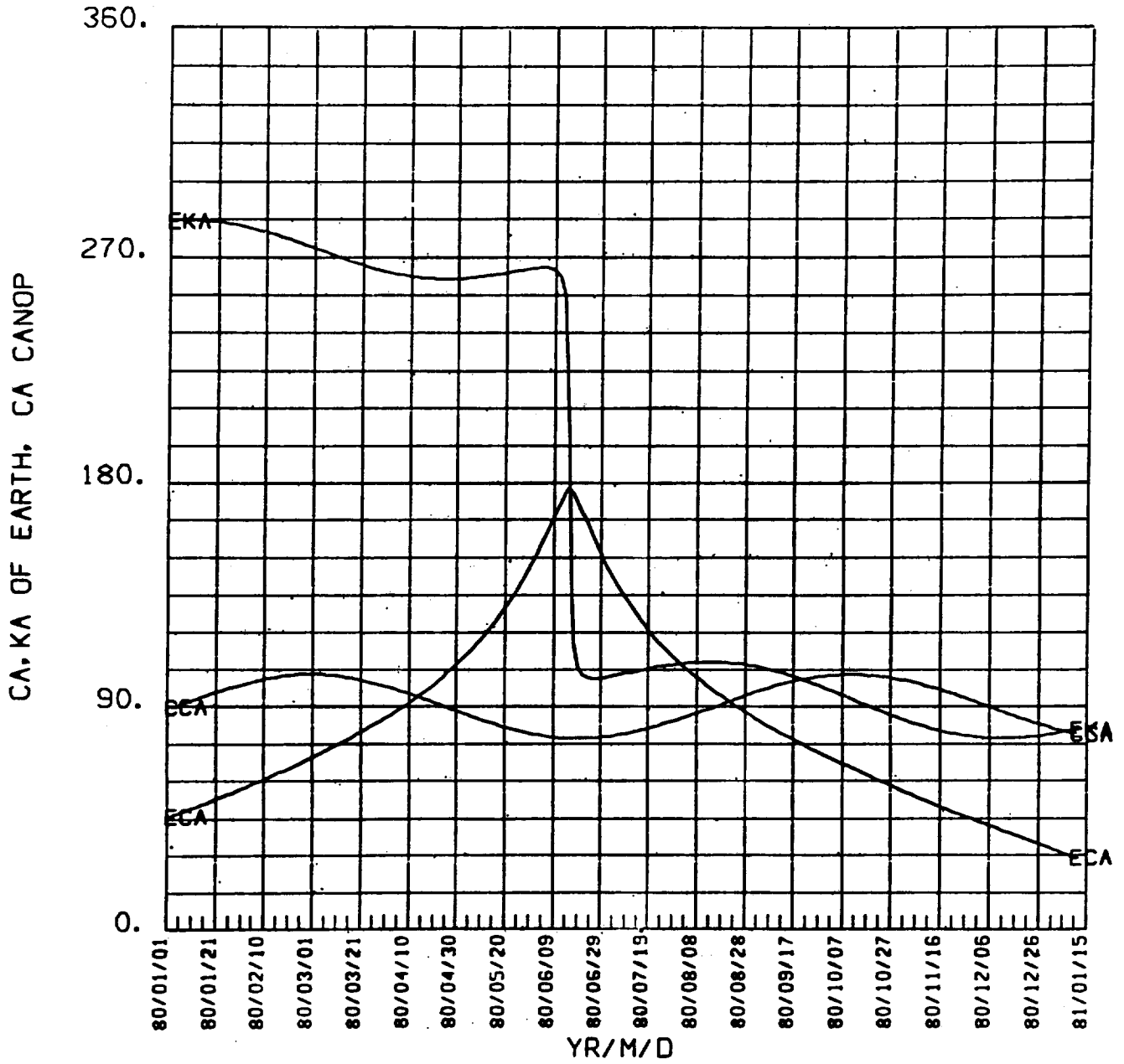
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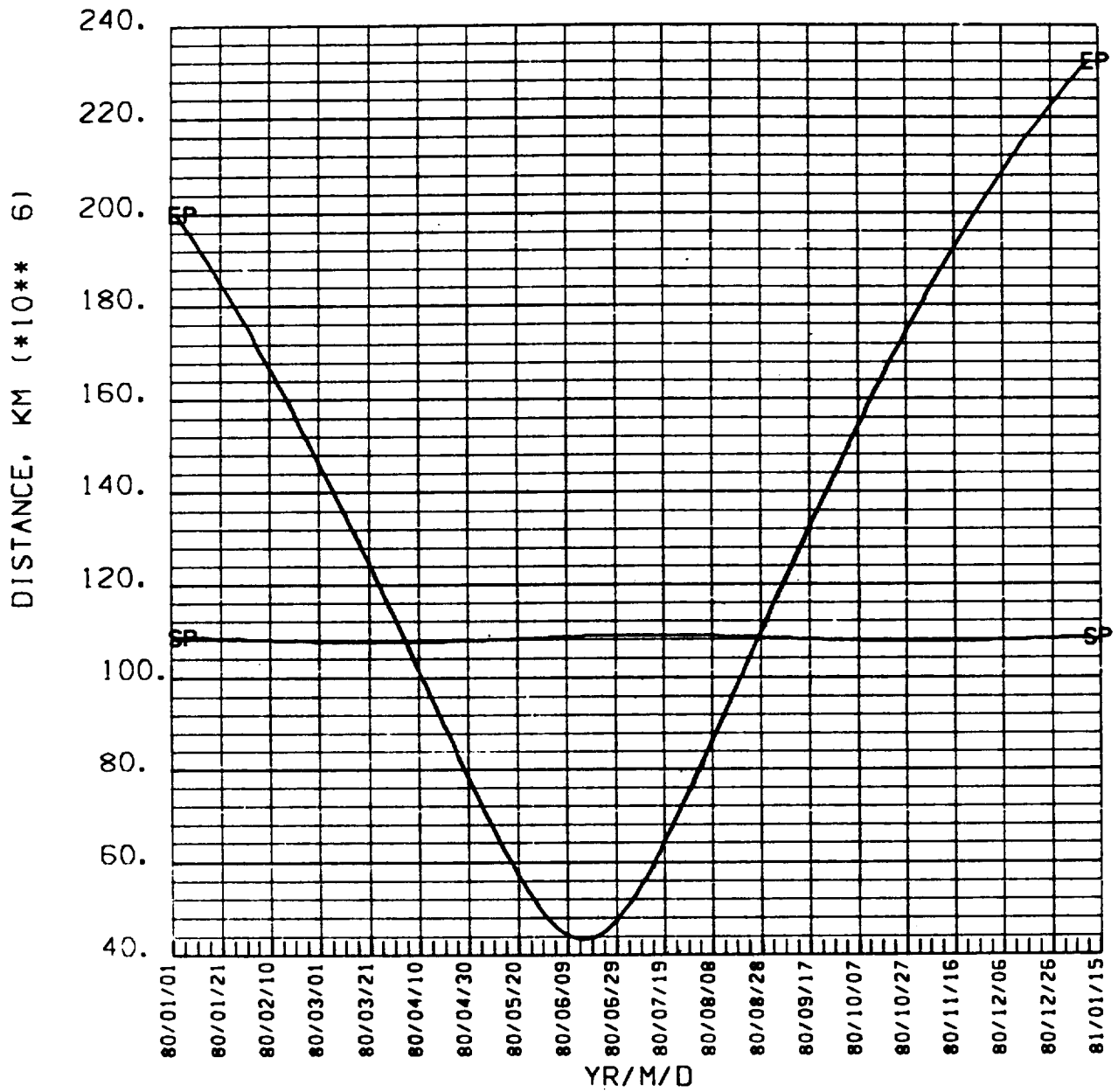
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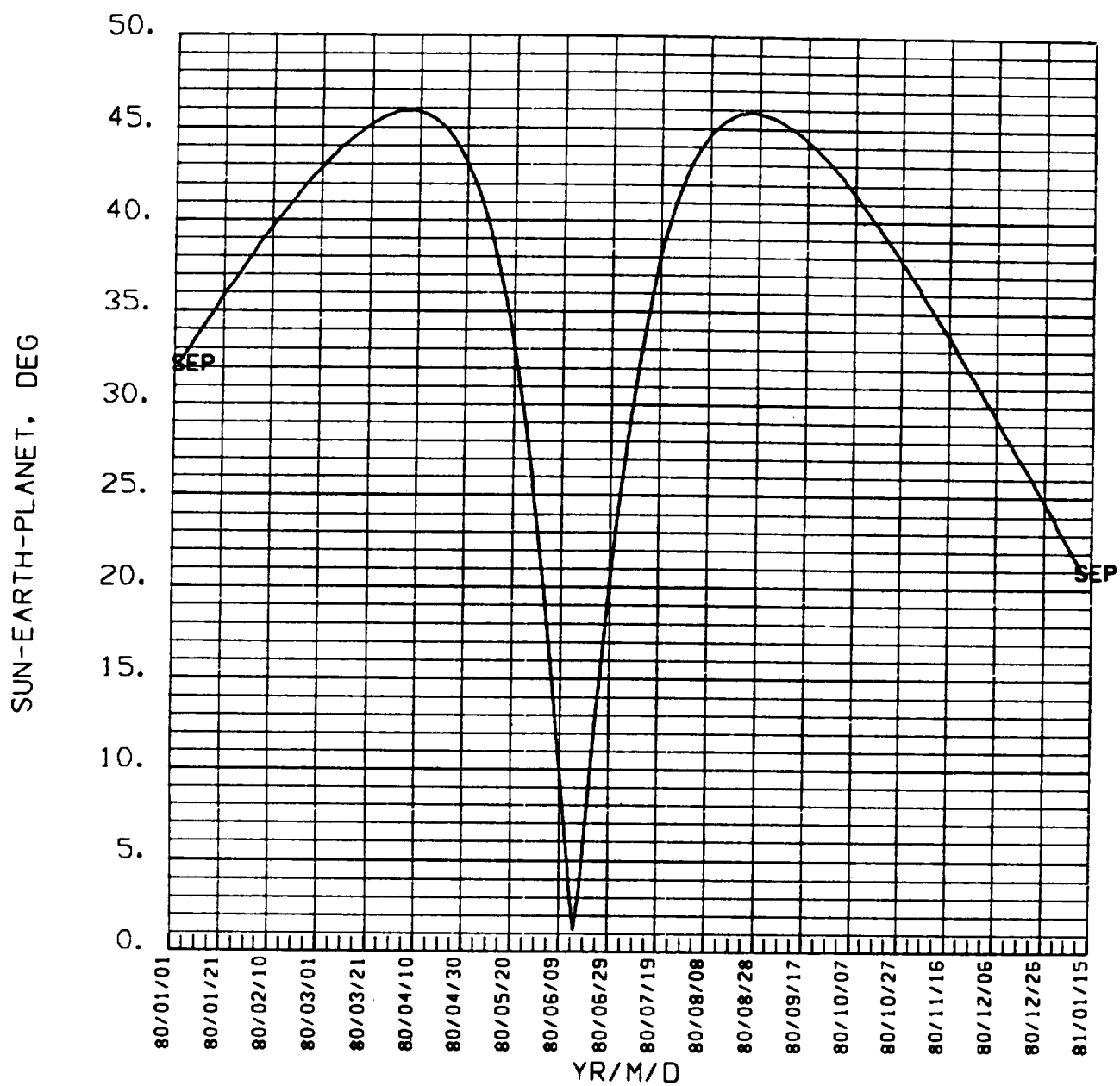
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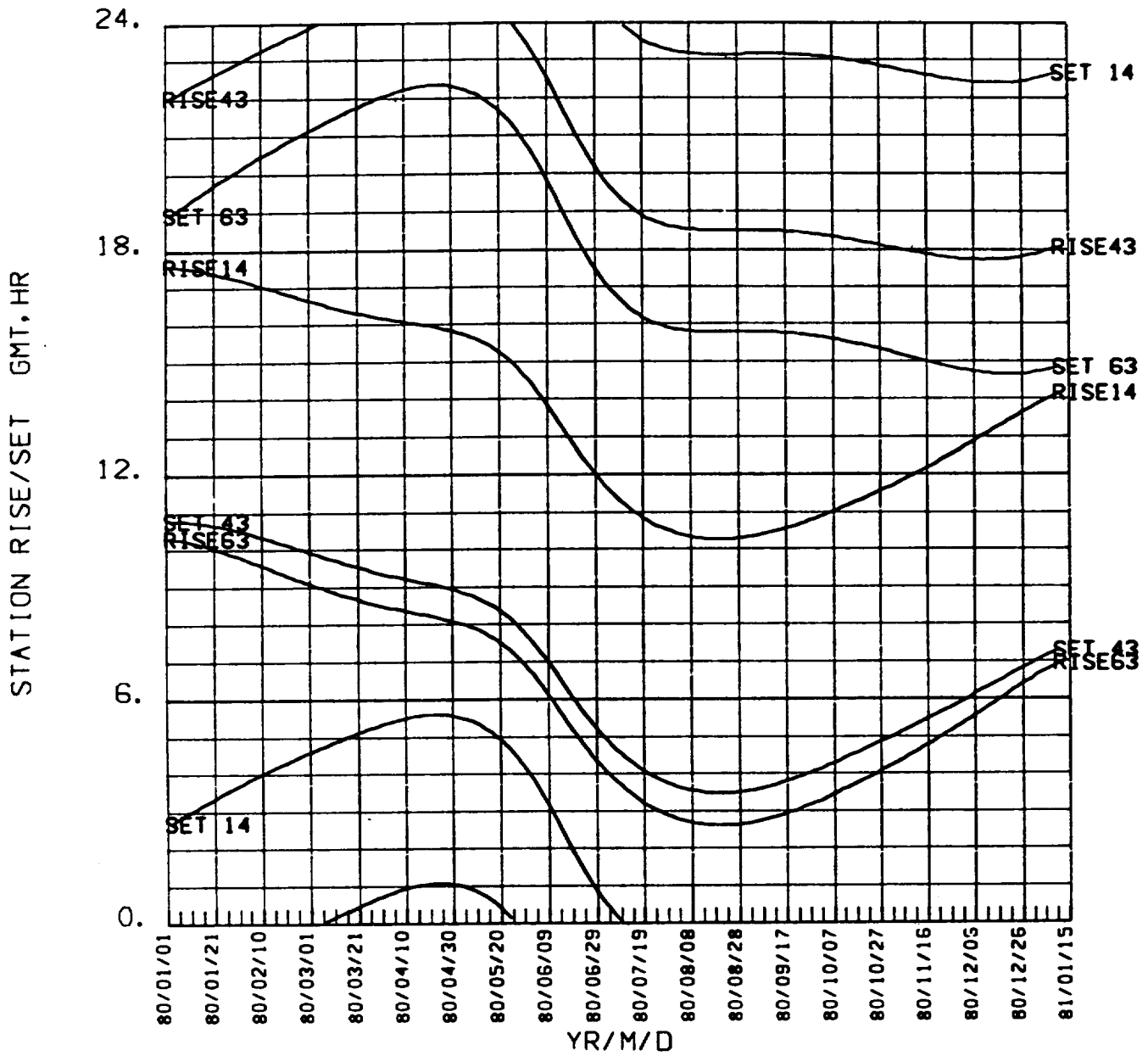
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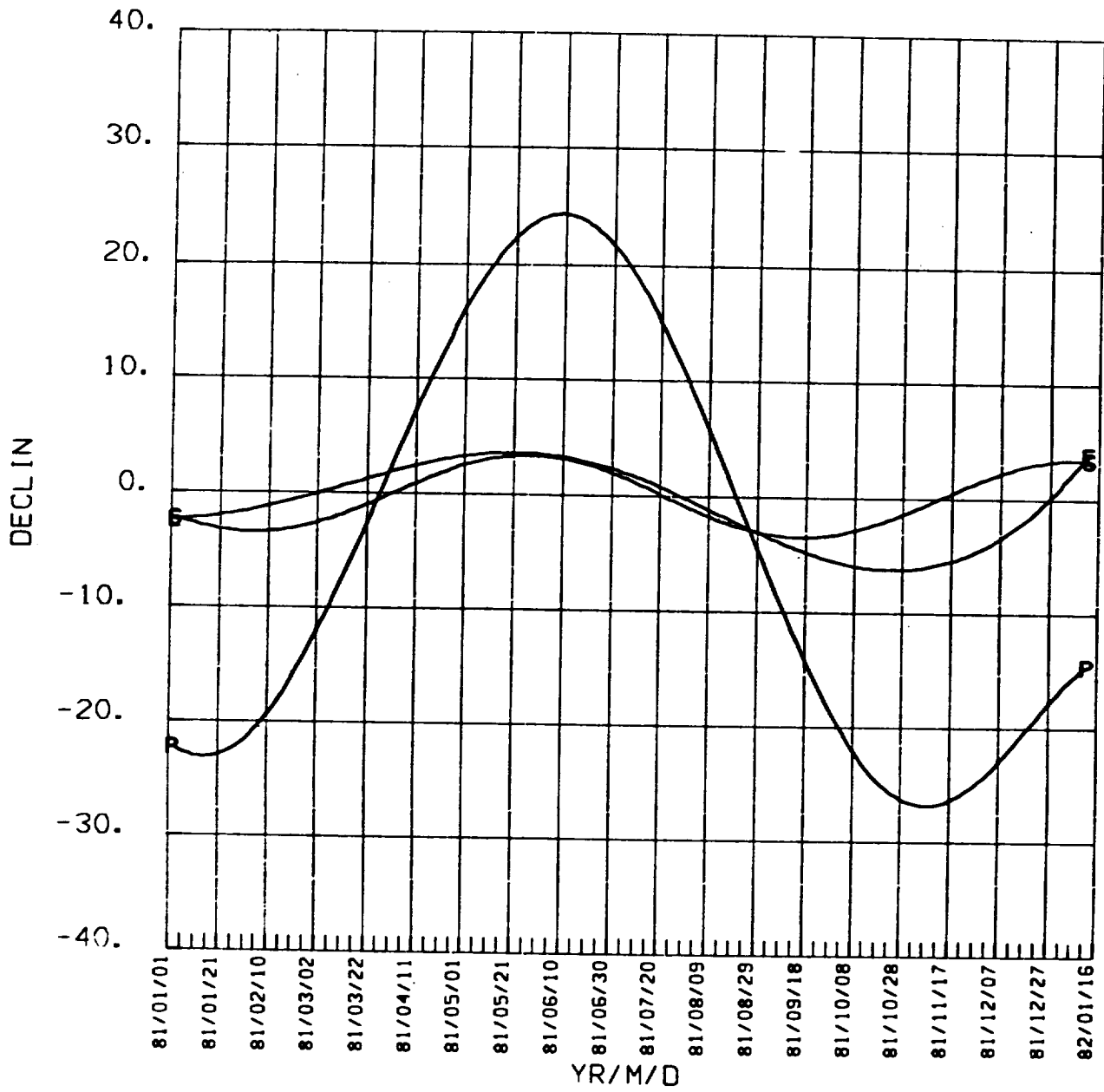
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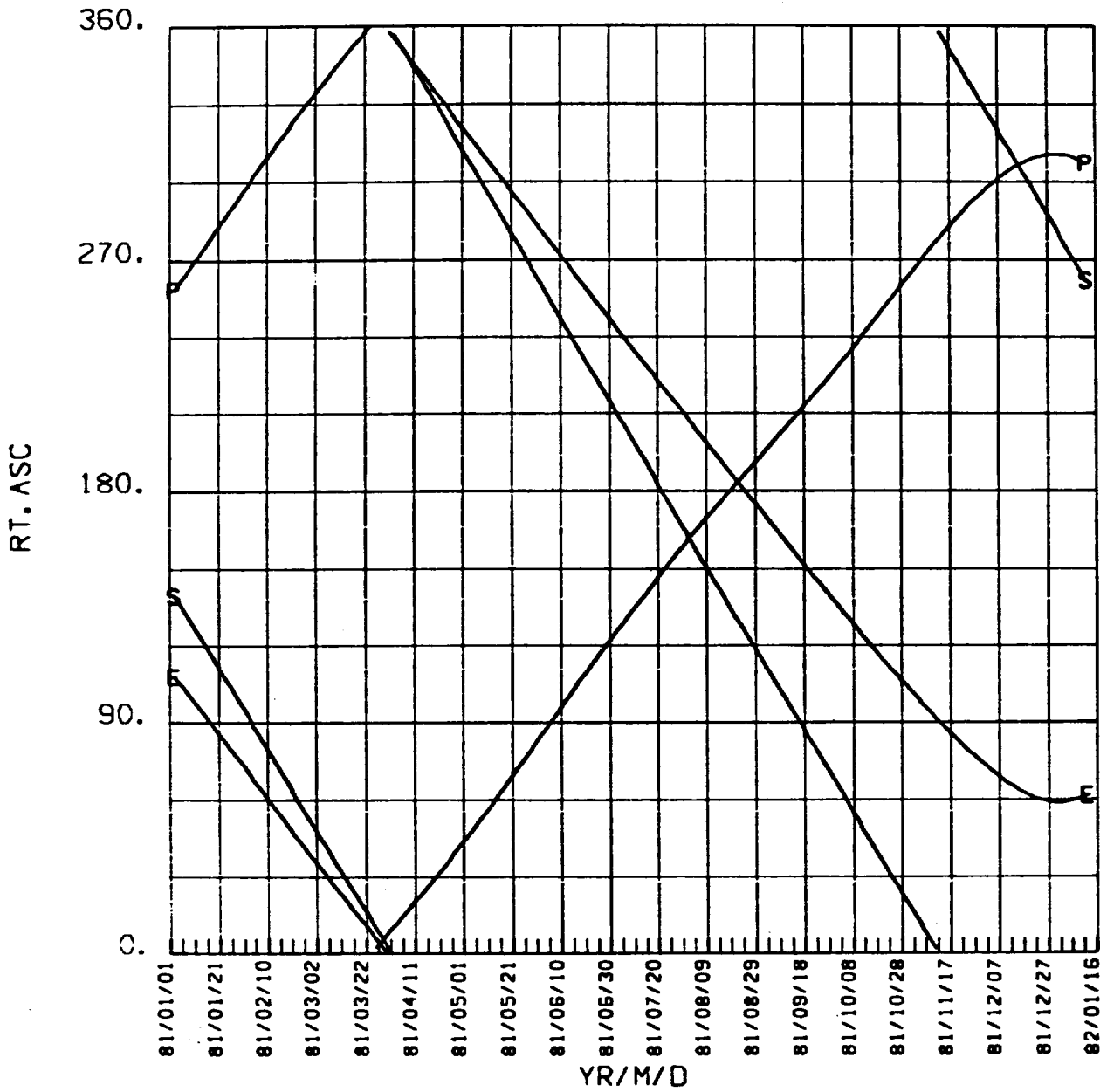
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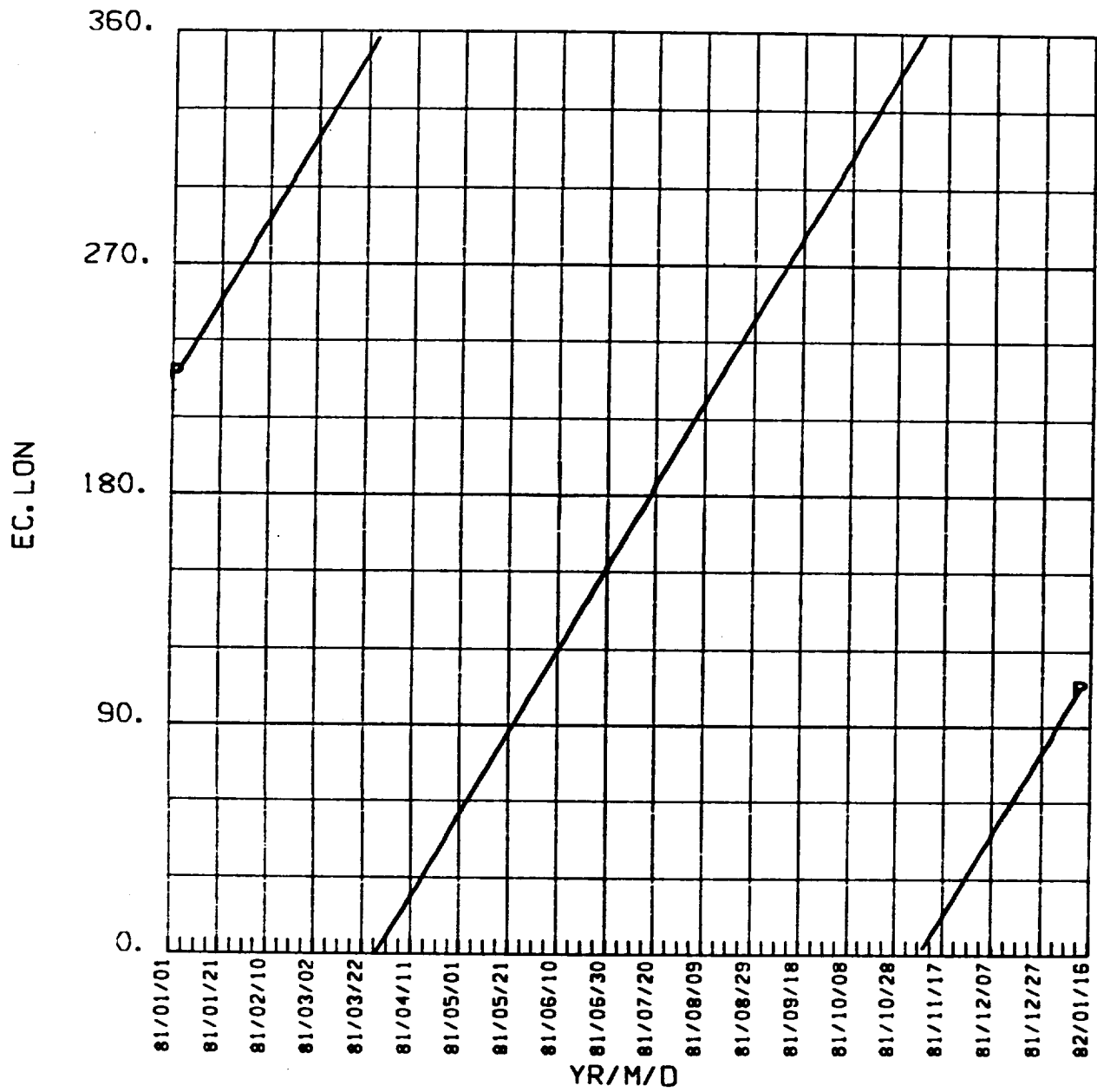


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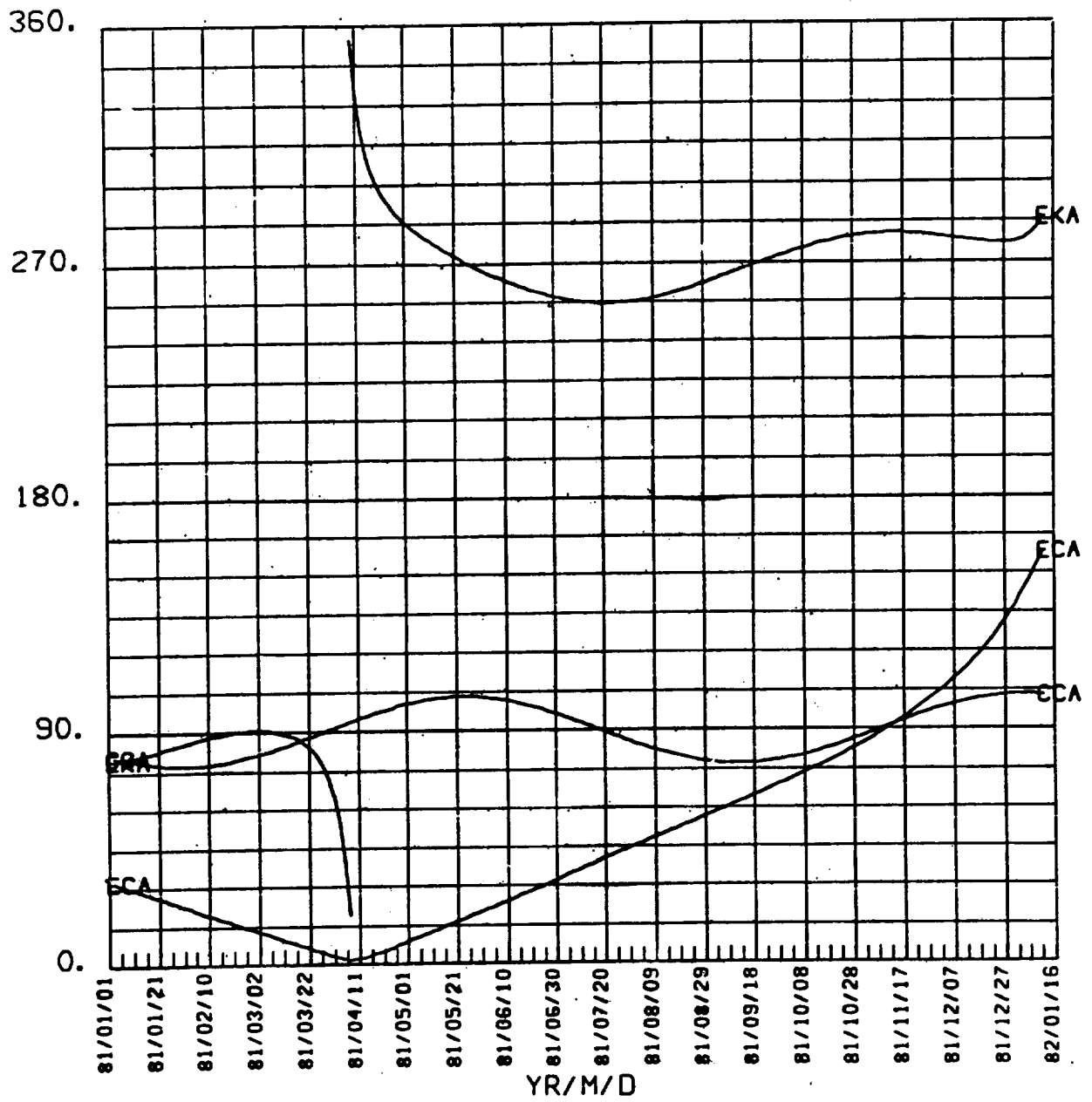
VENUS 1981



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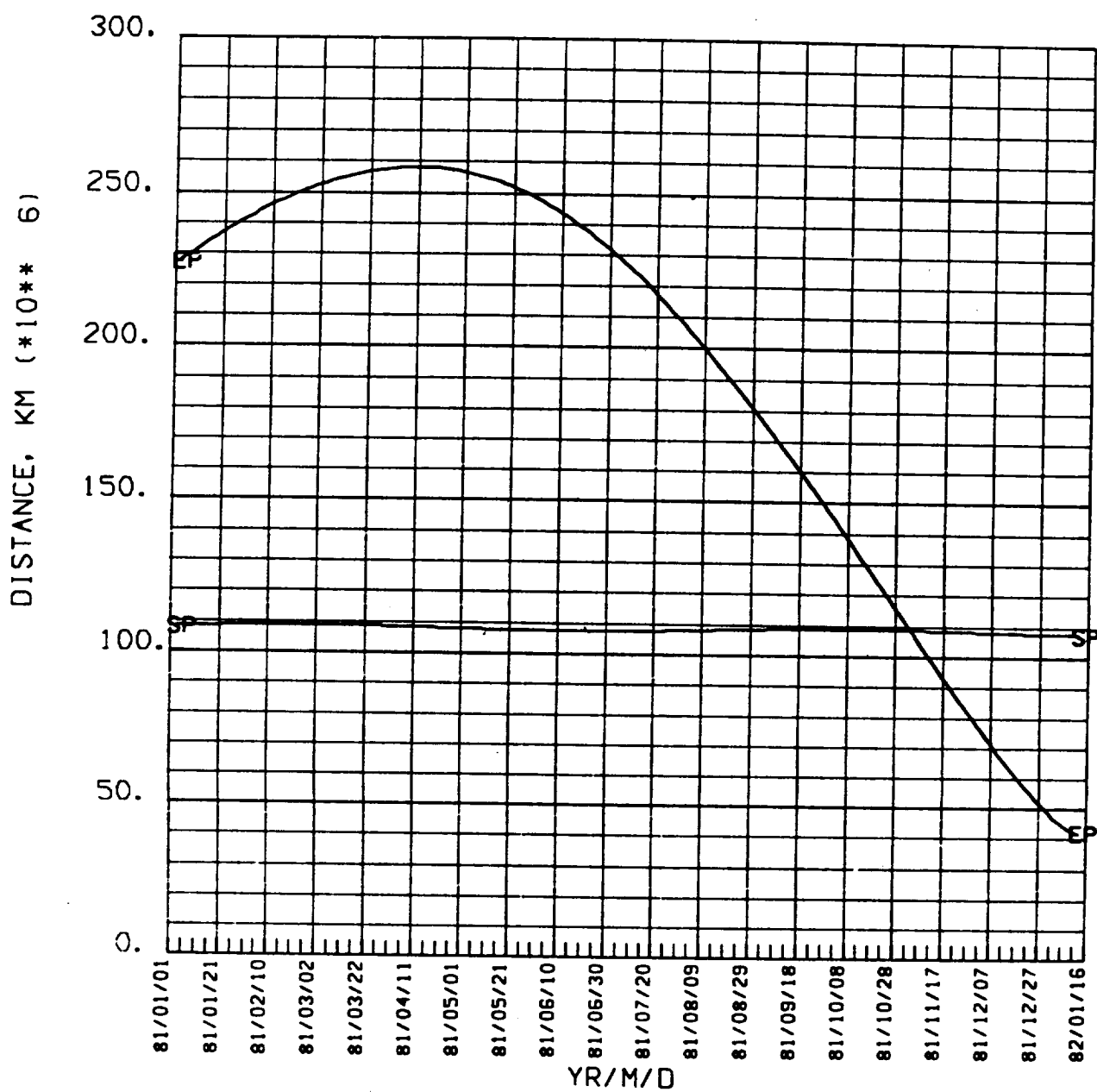
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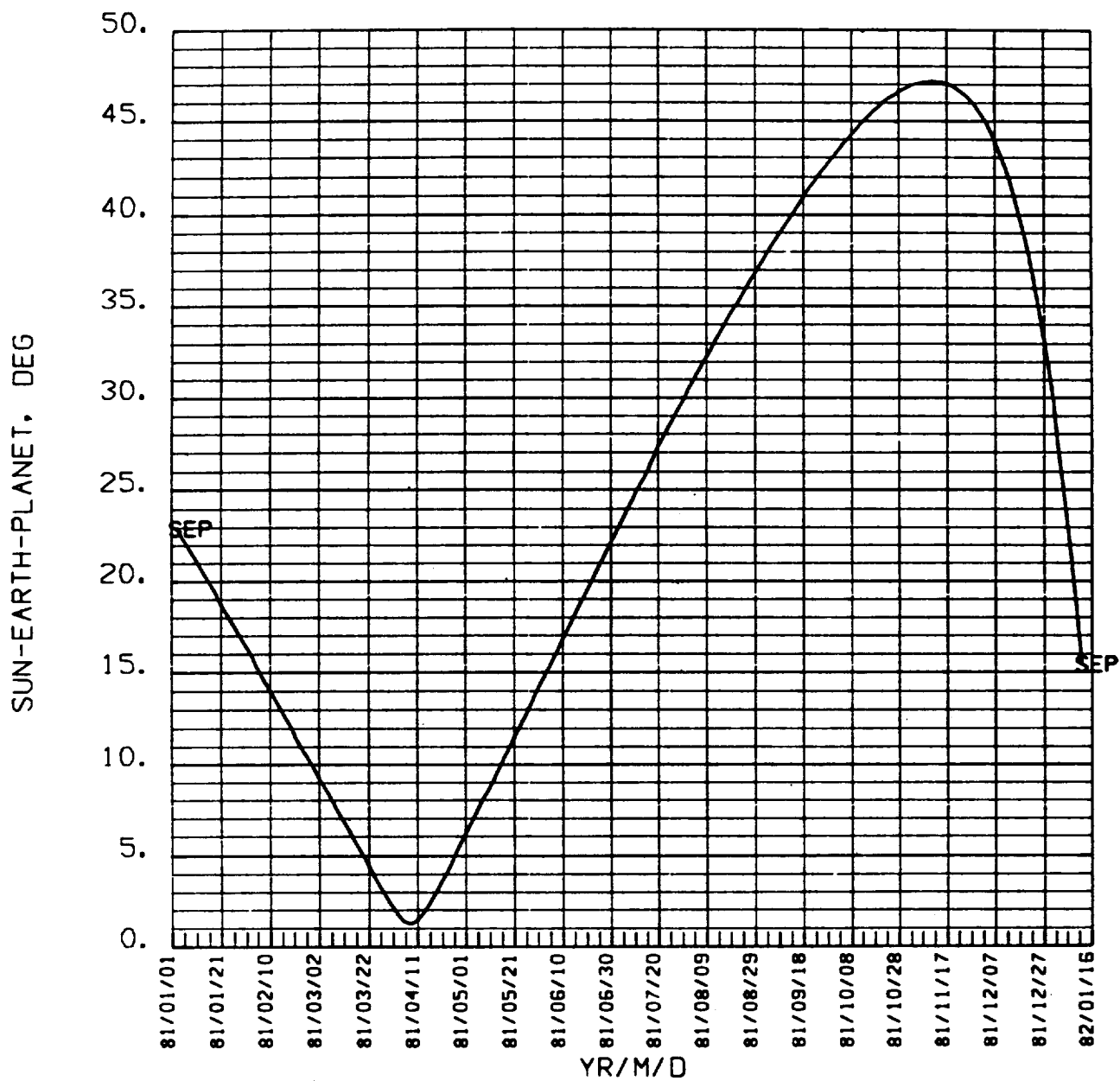
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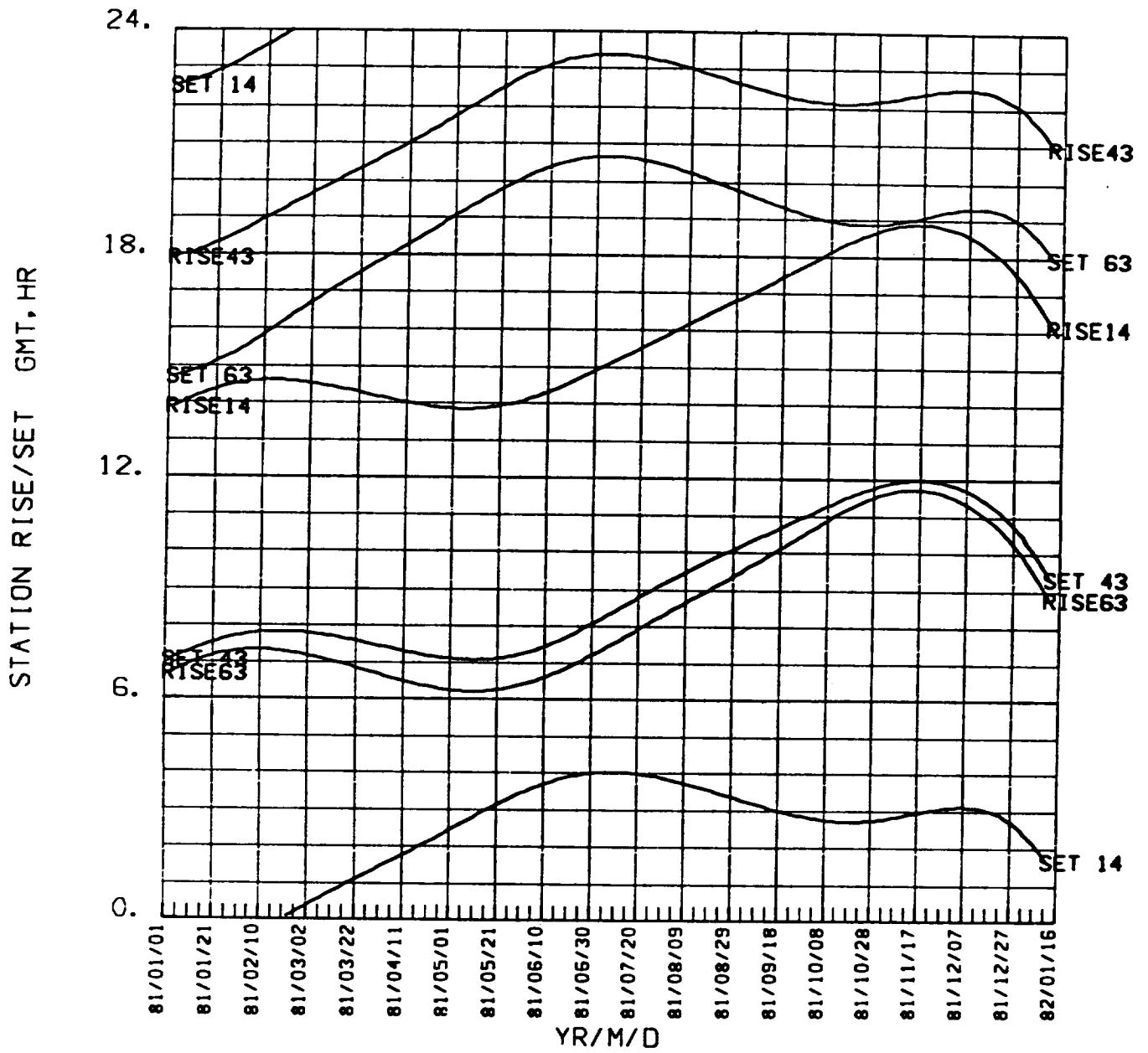
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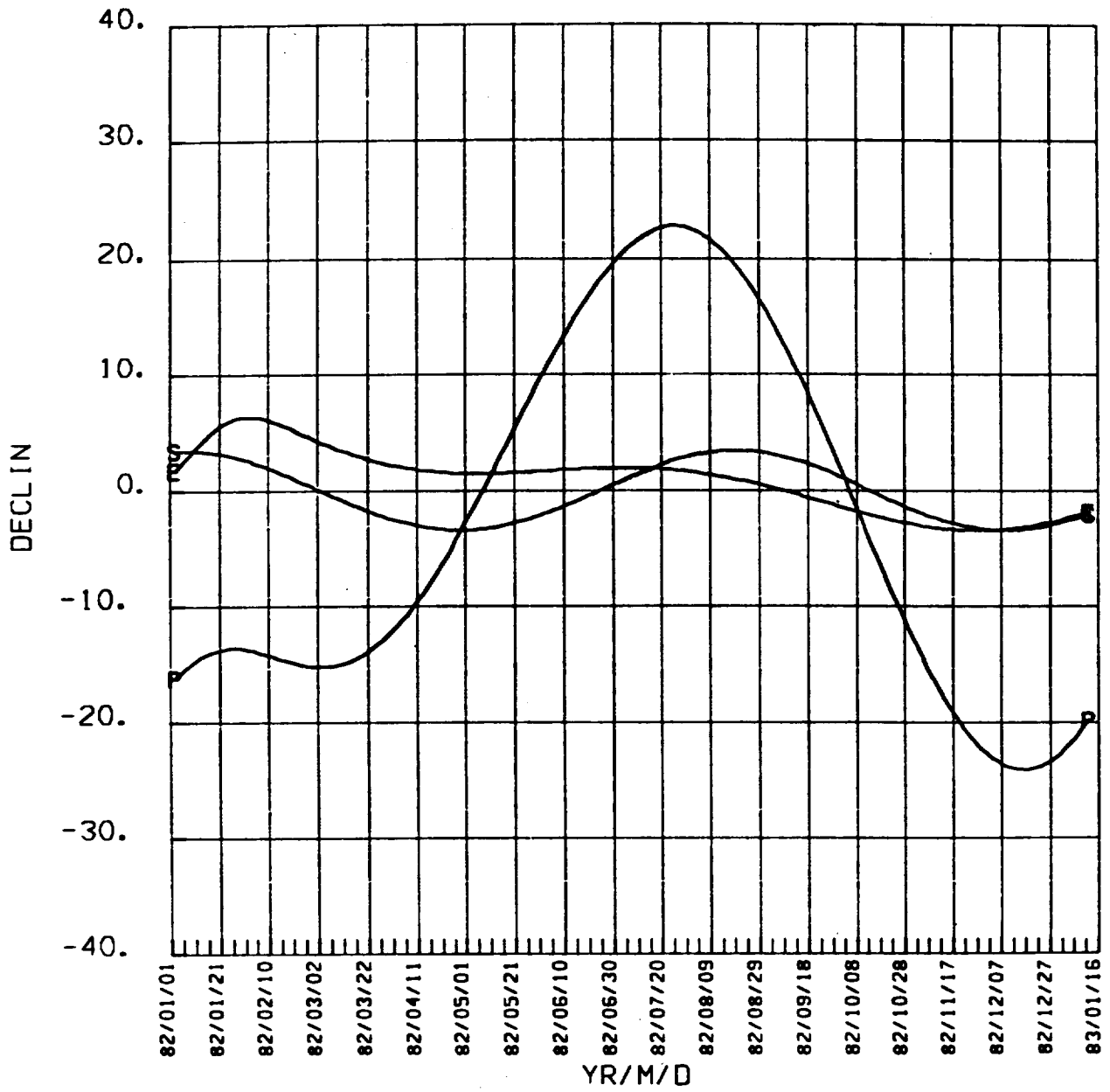
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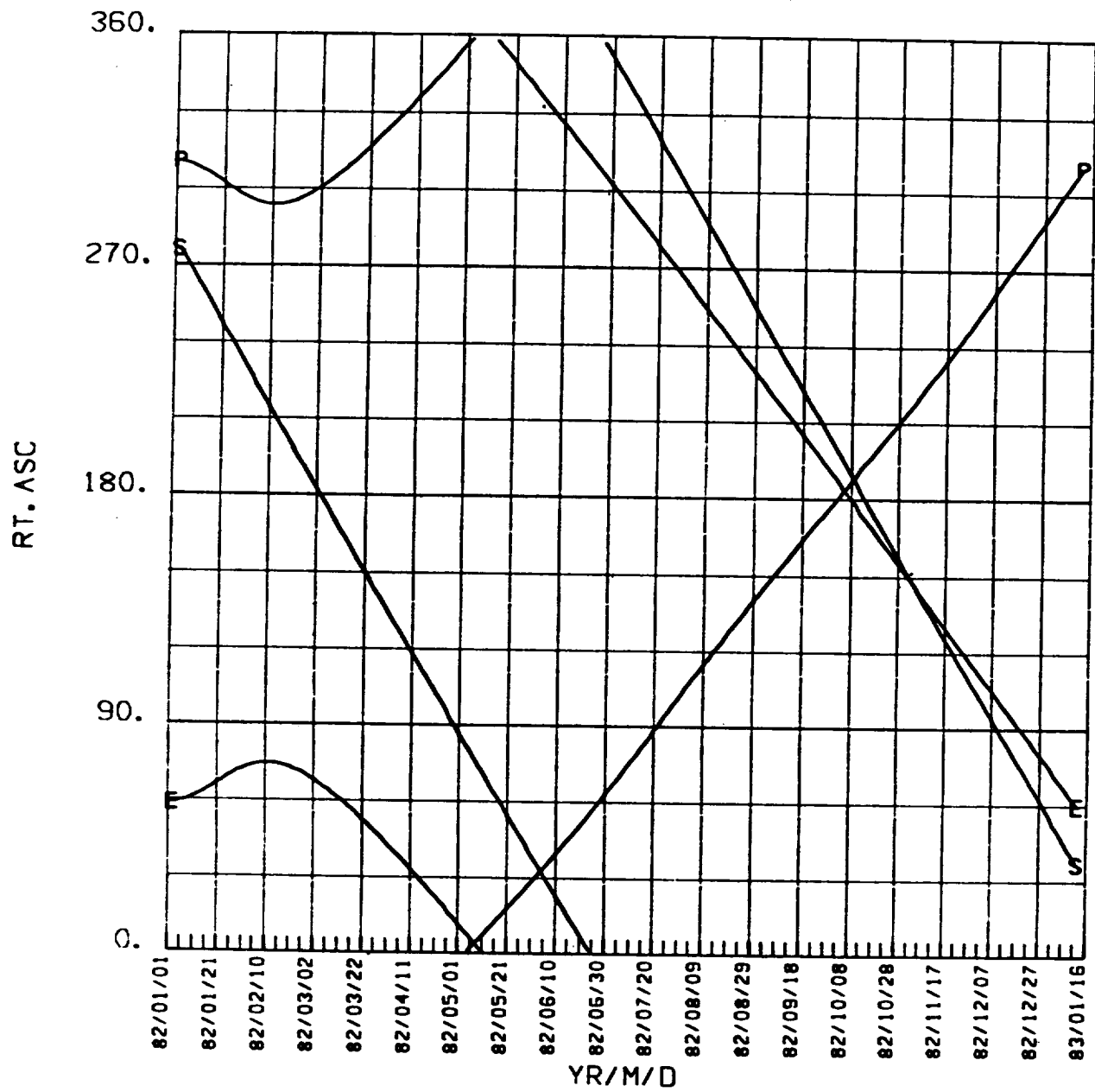
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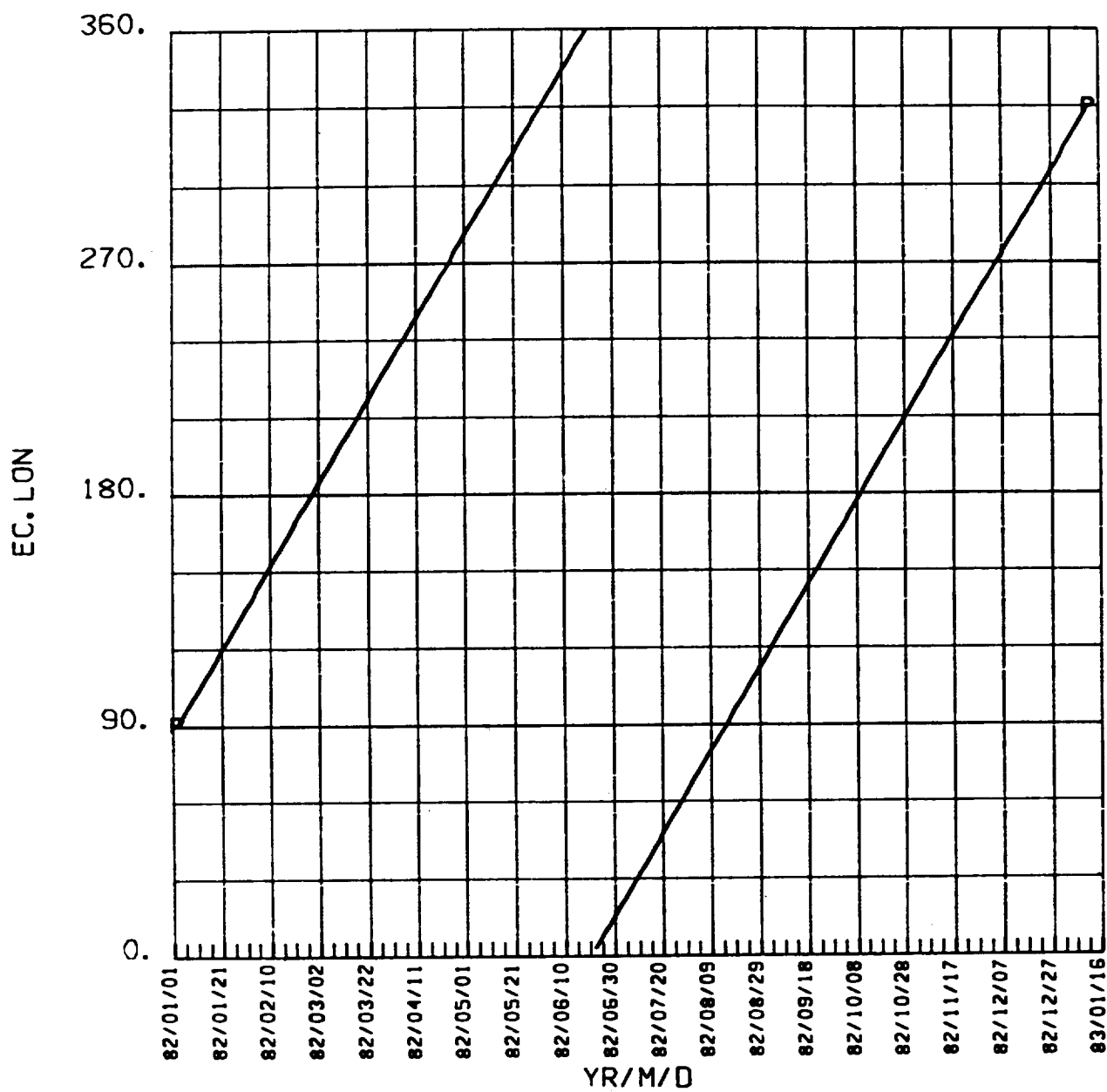
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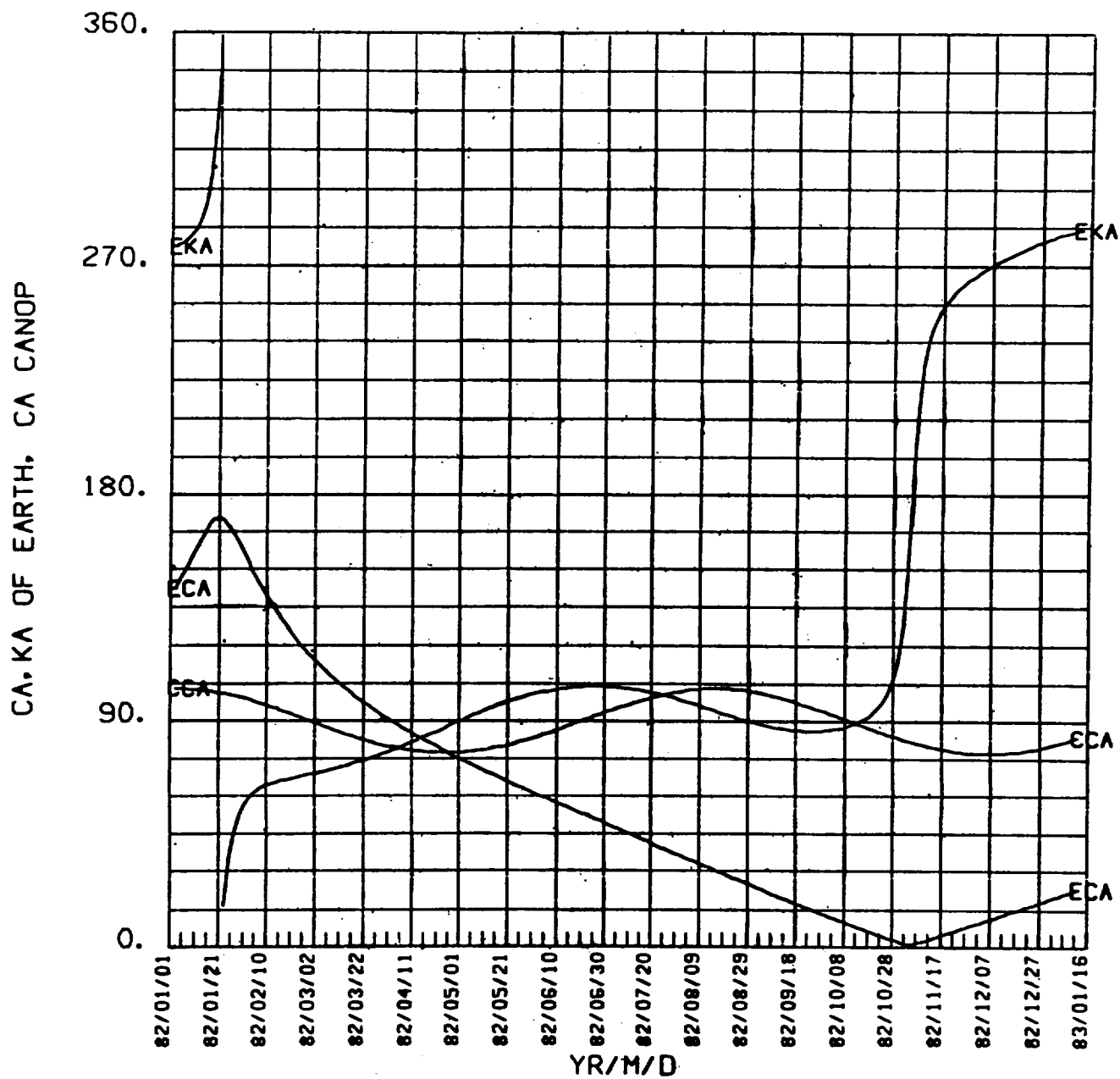
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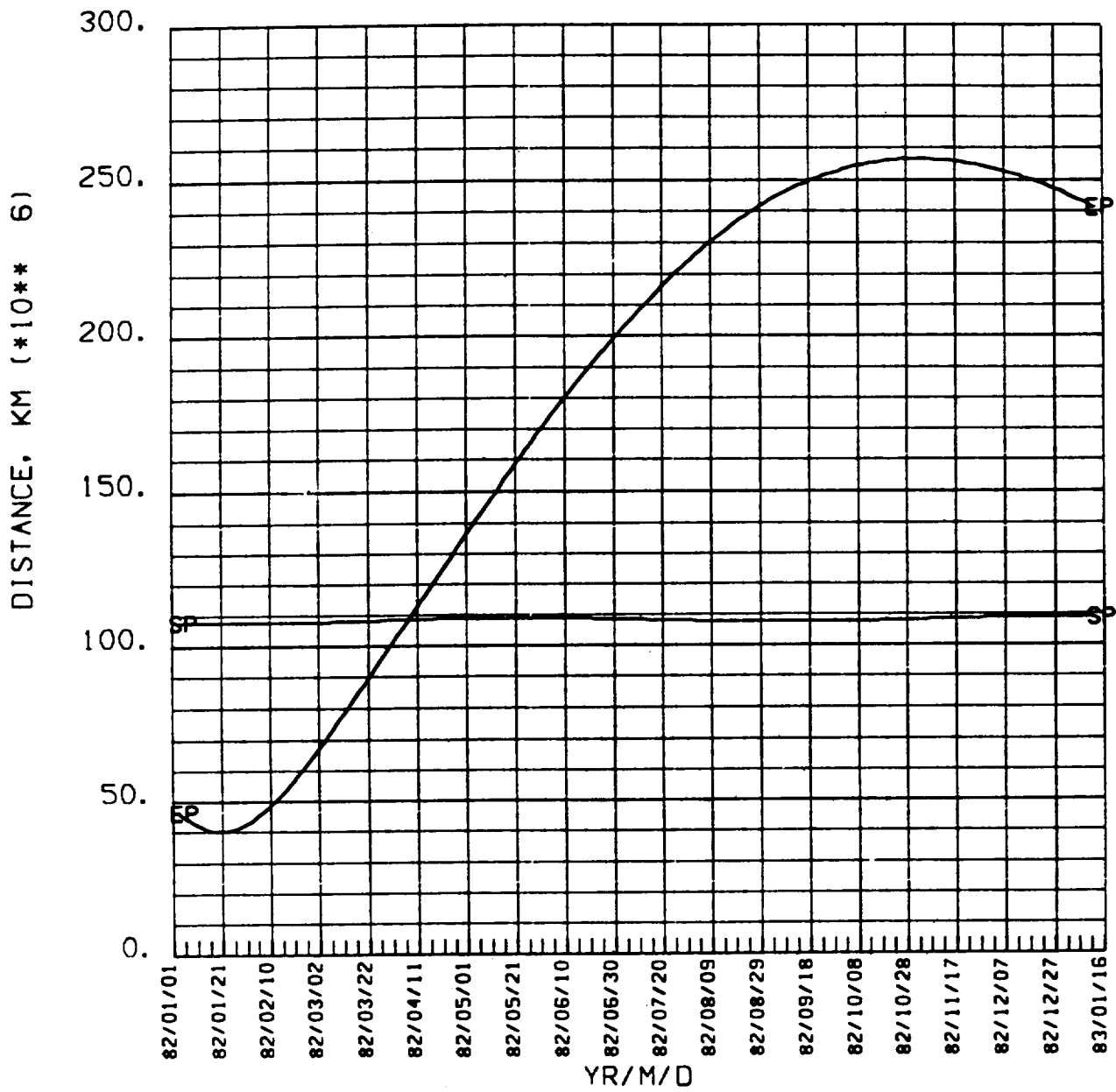
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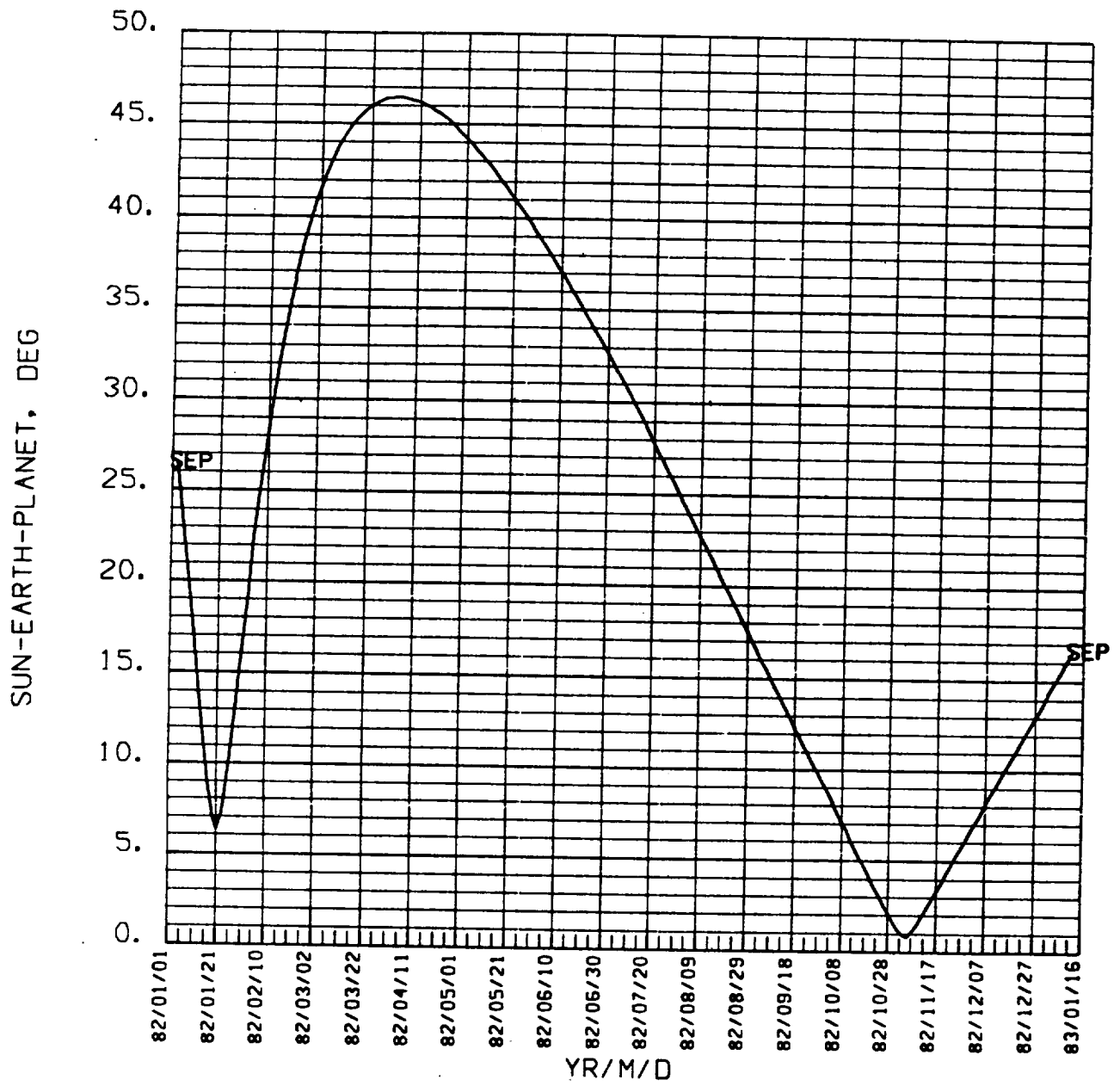
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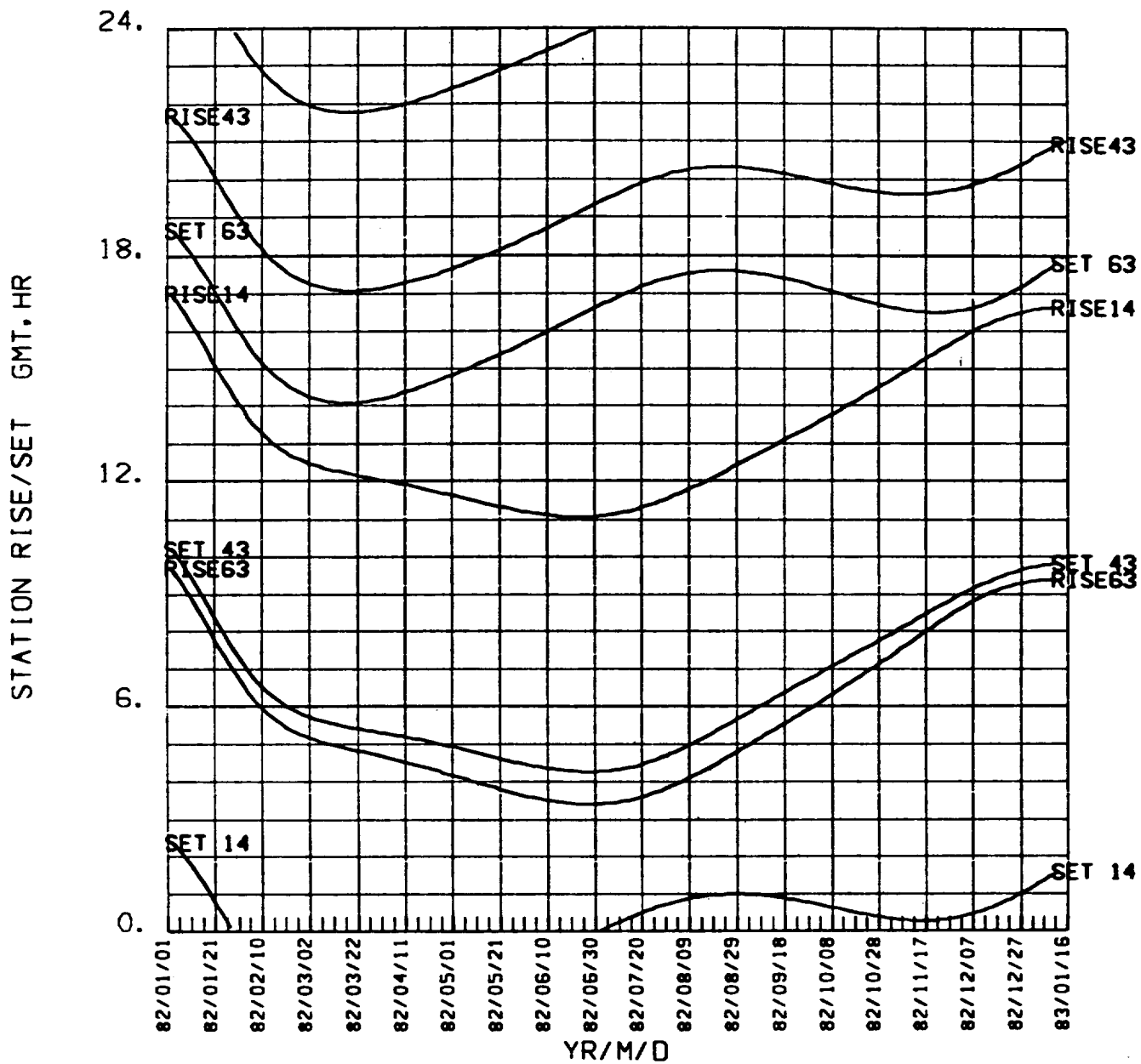
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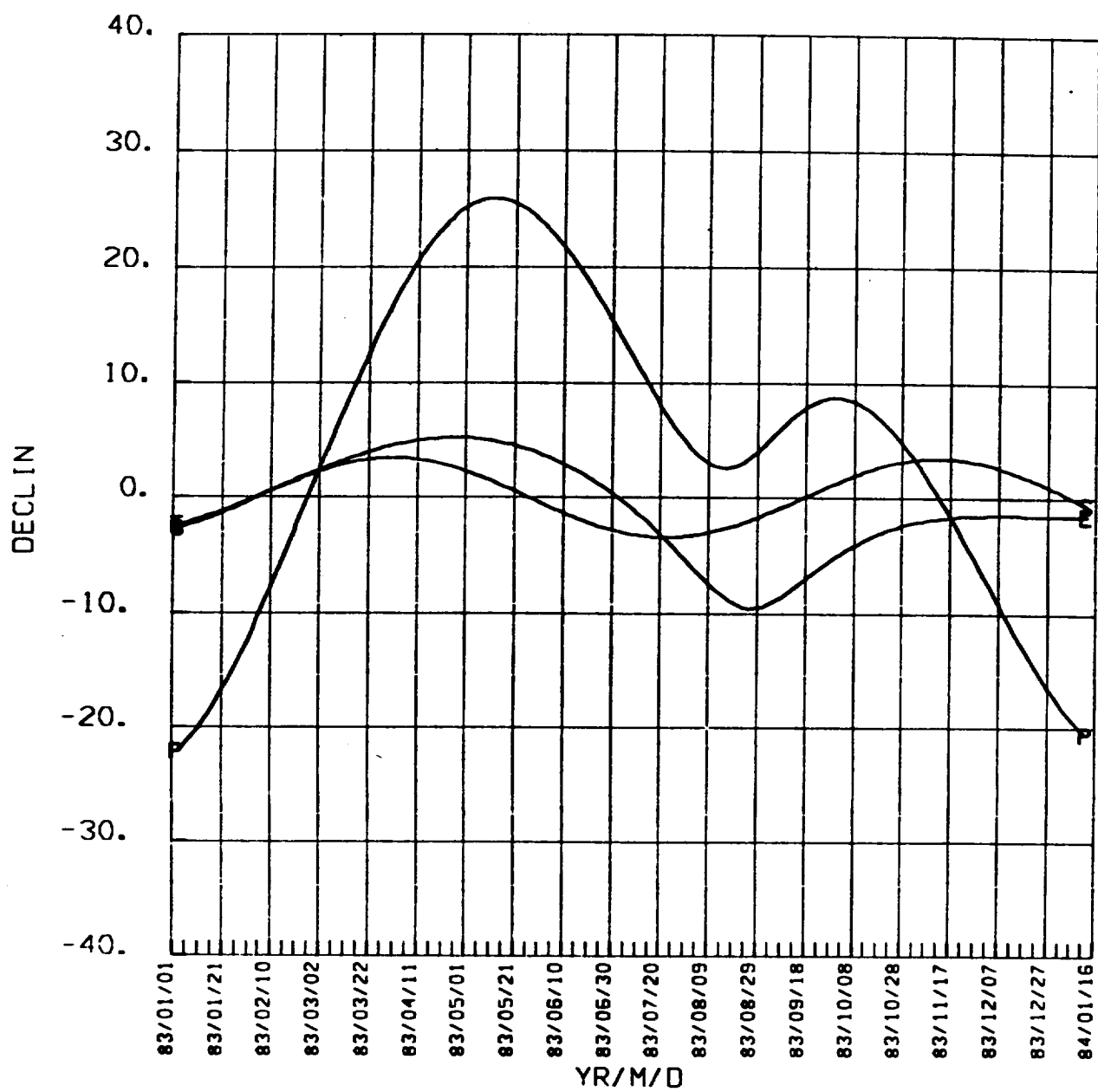
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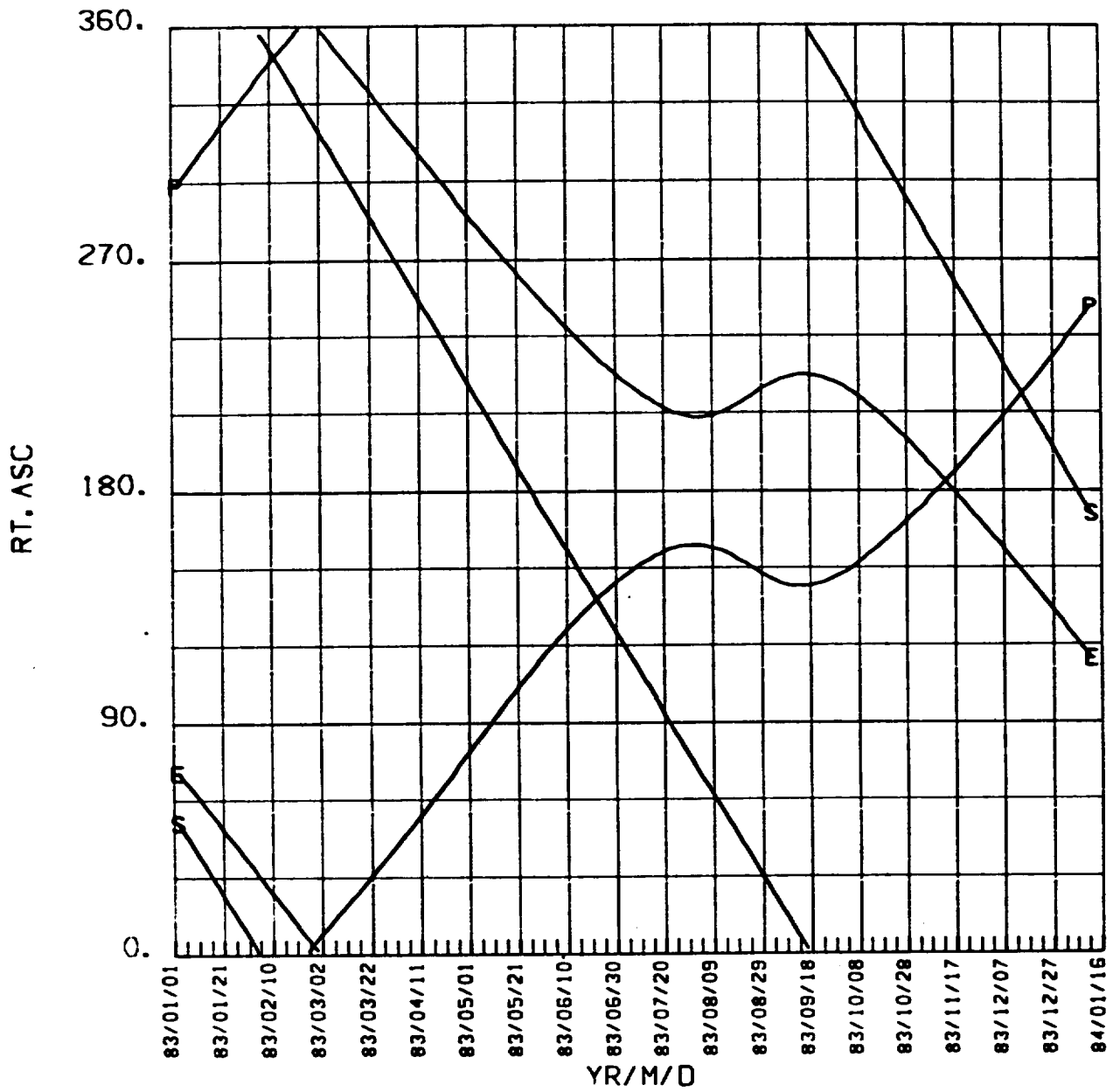
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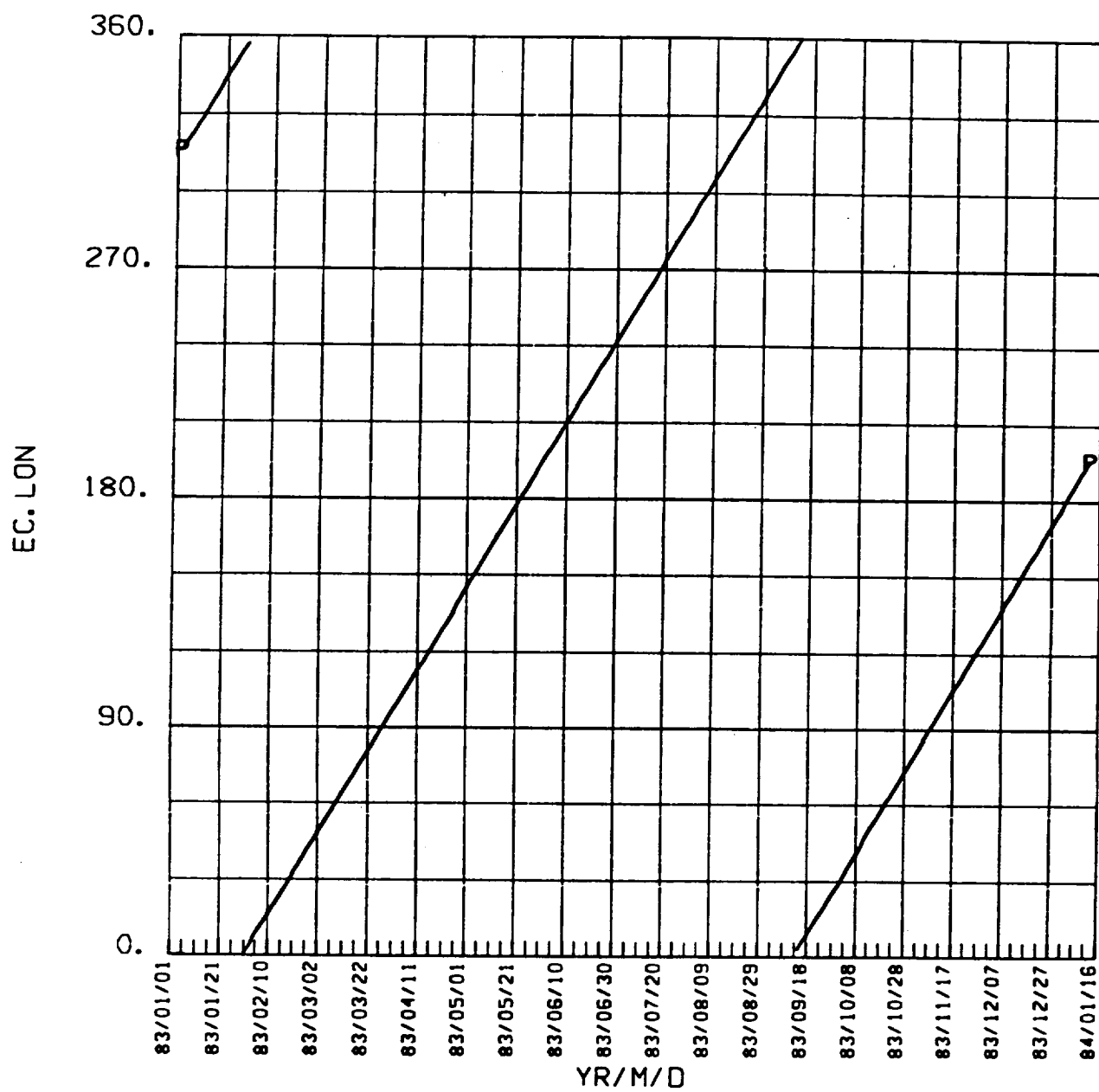
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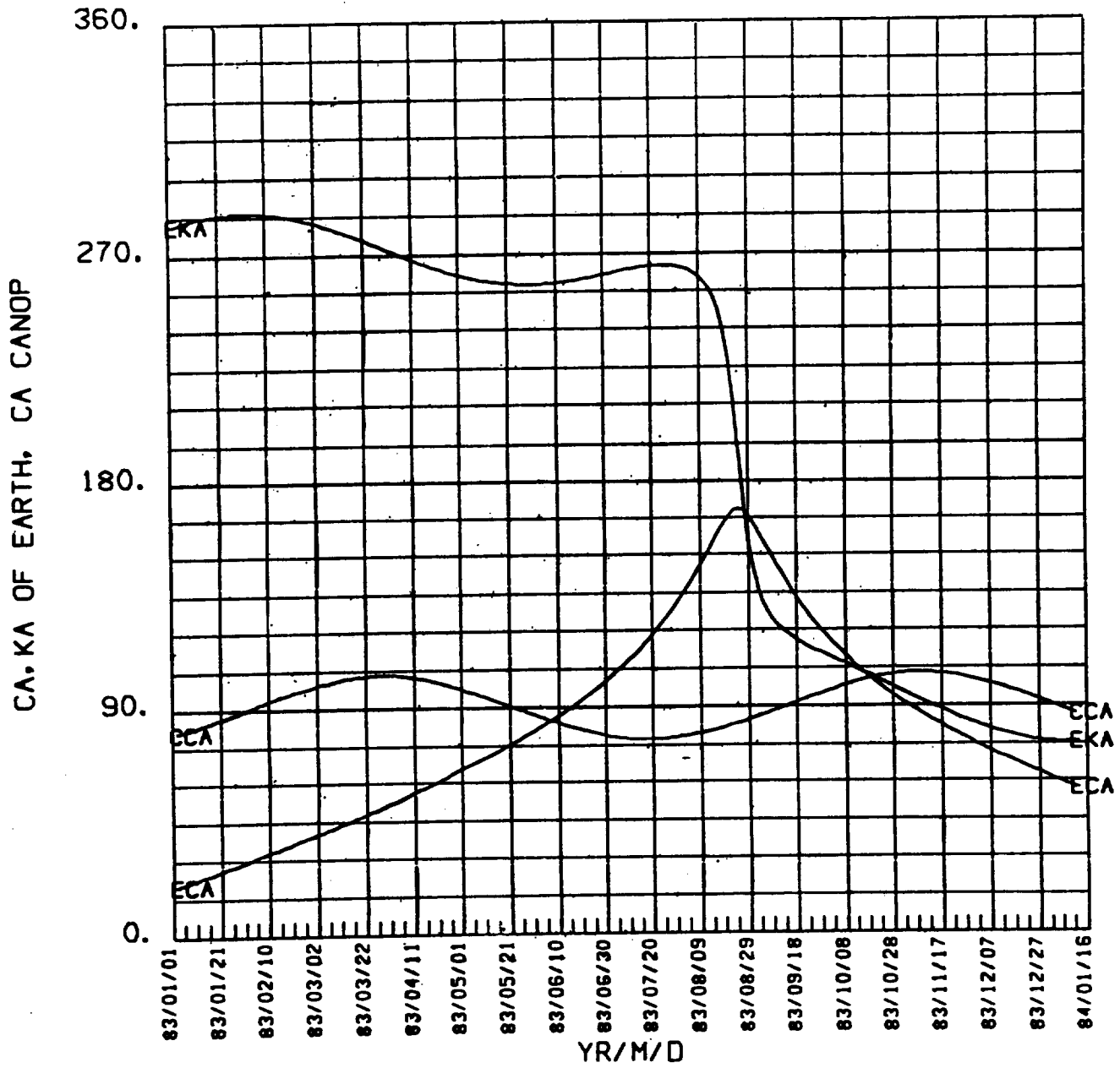
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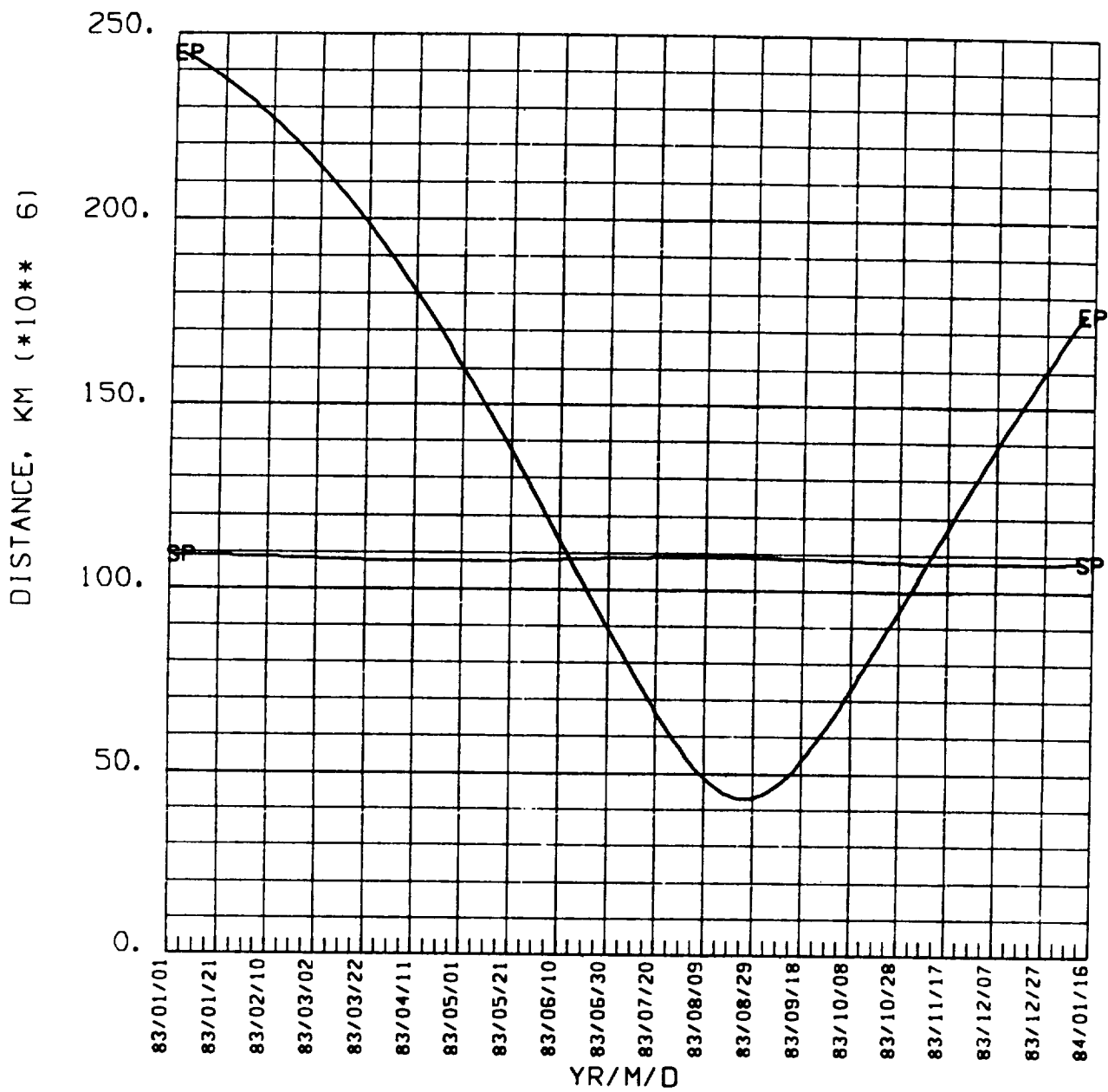


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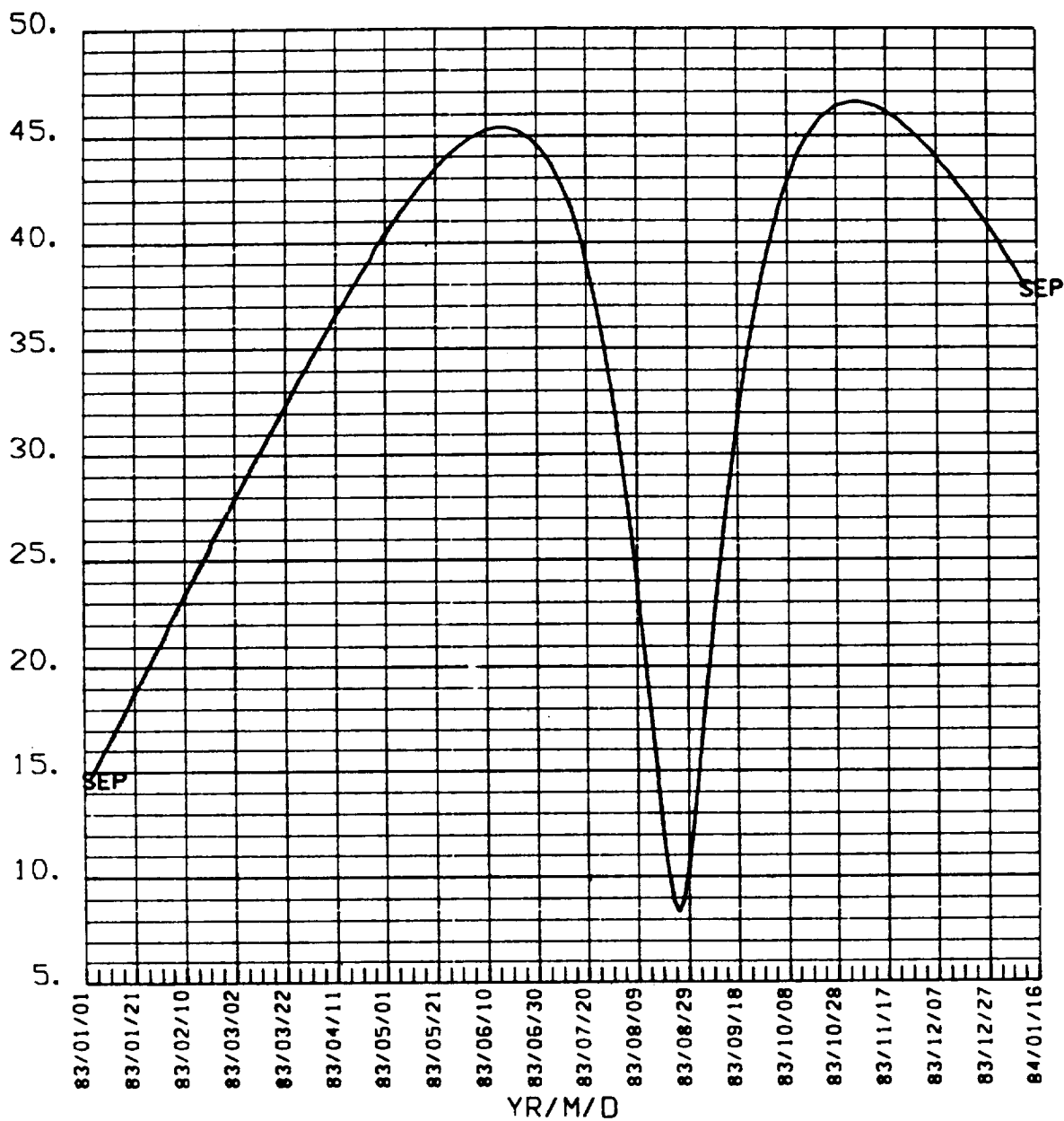


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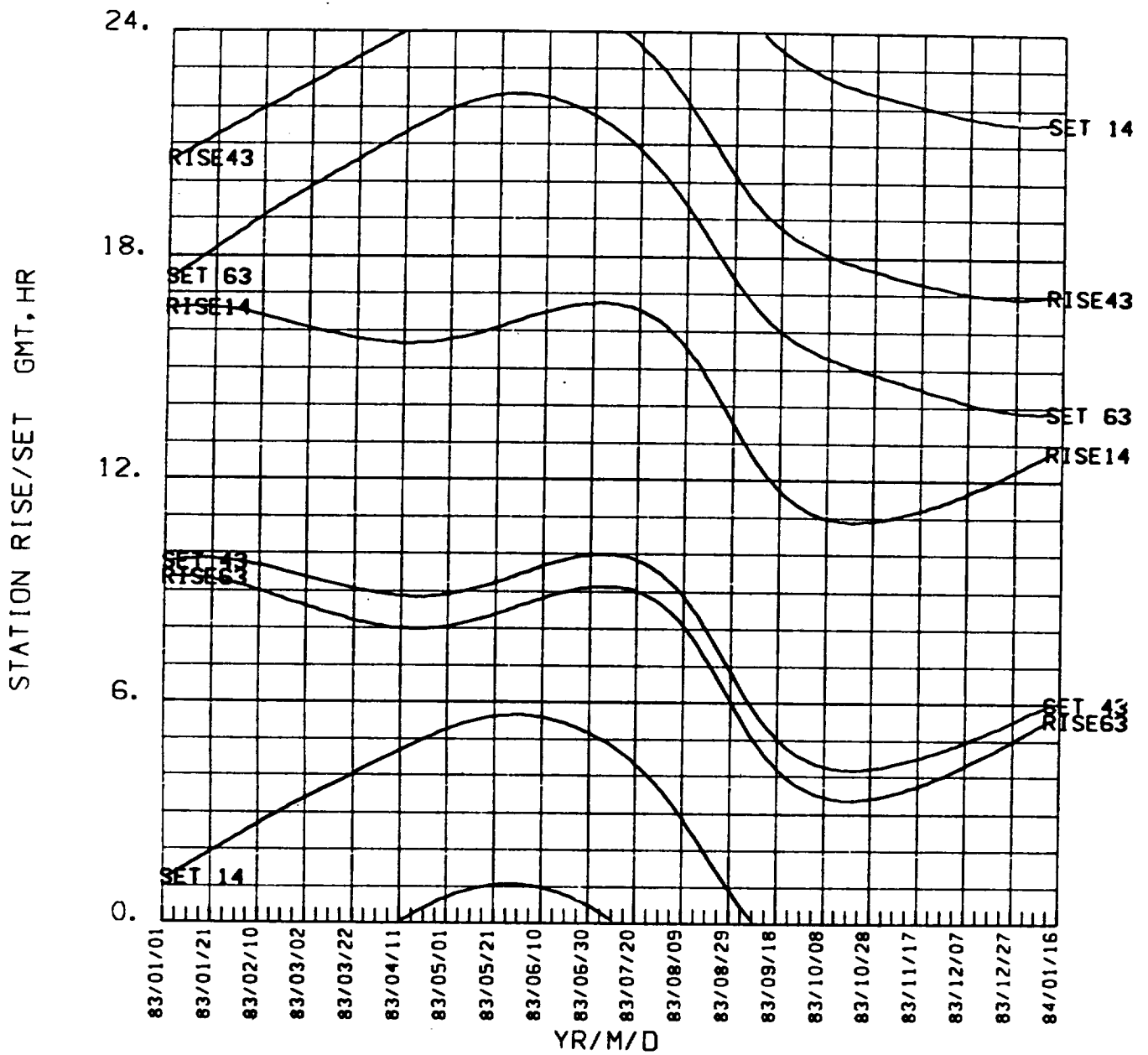


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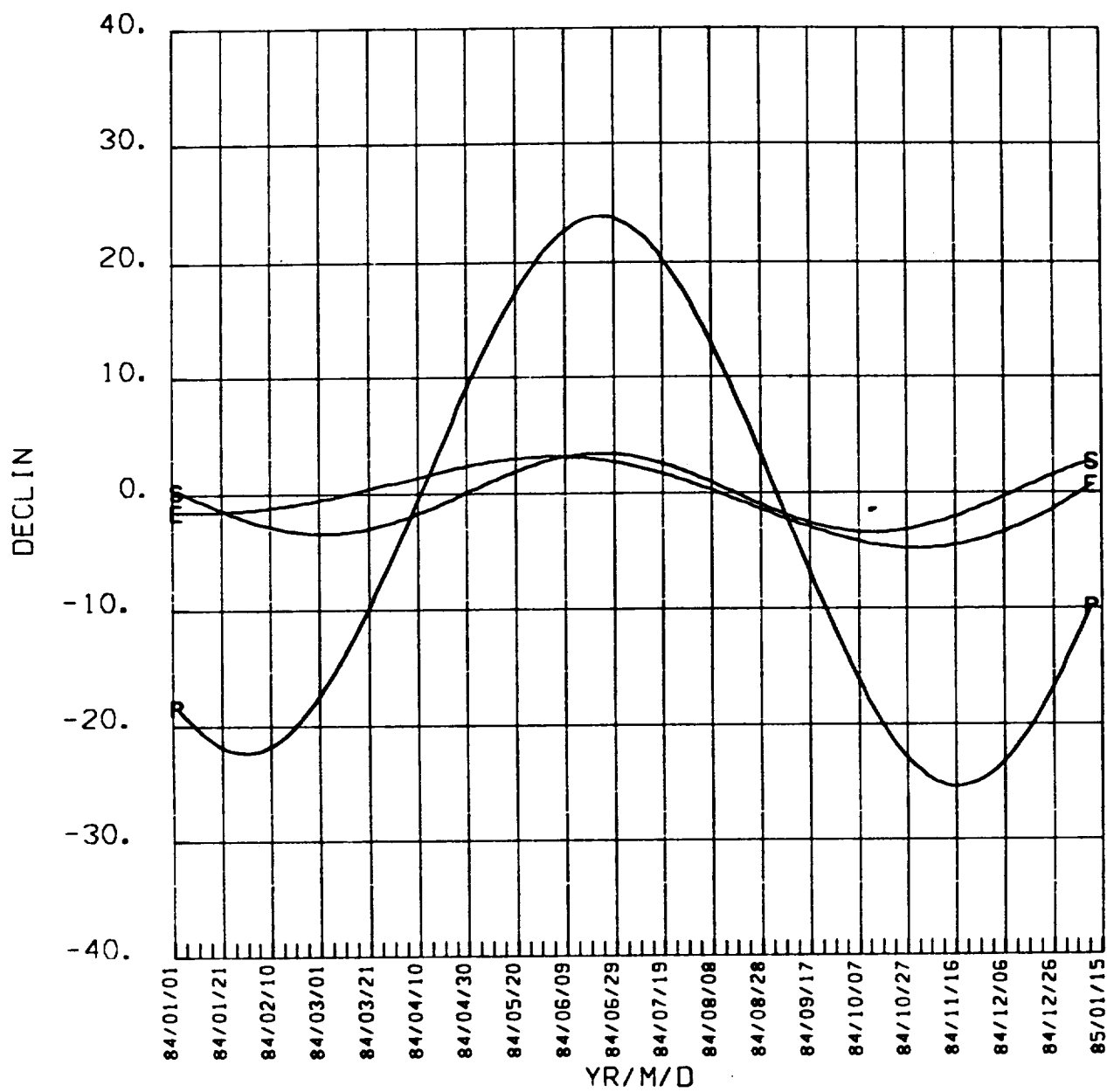
SUN-EARTH-PLANET. DEG



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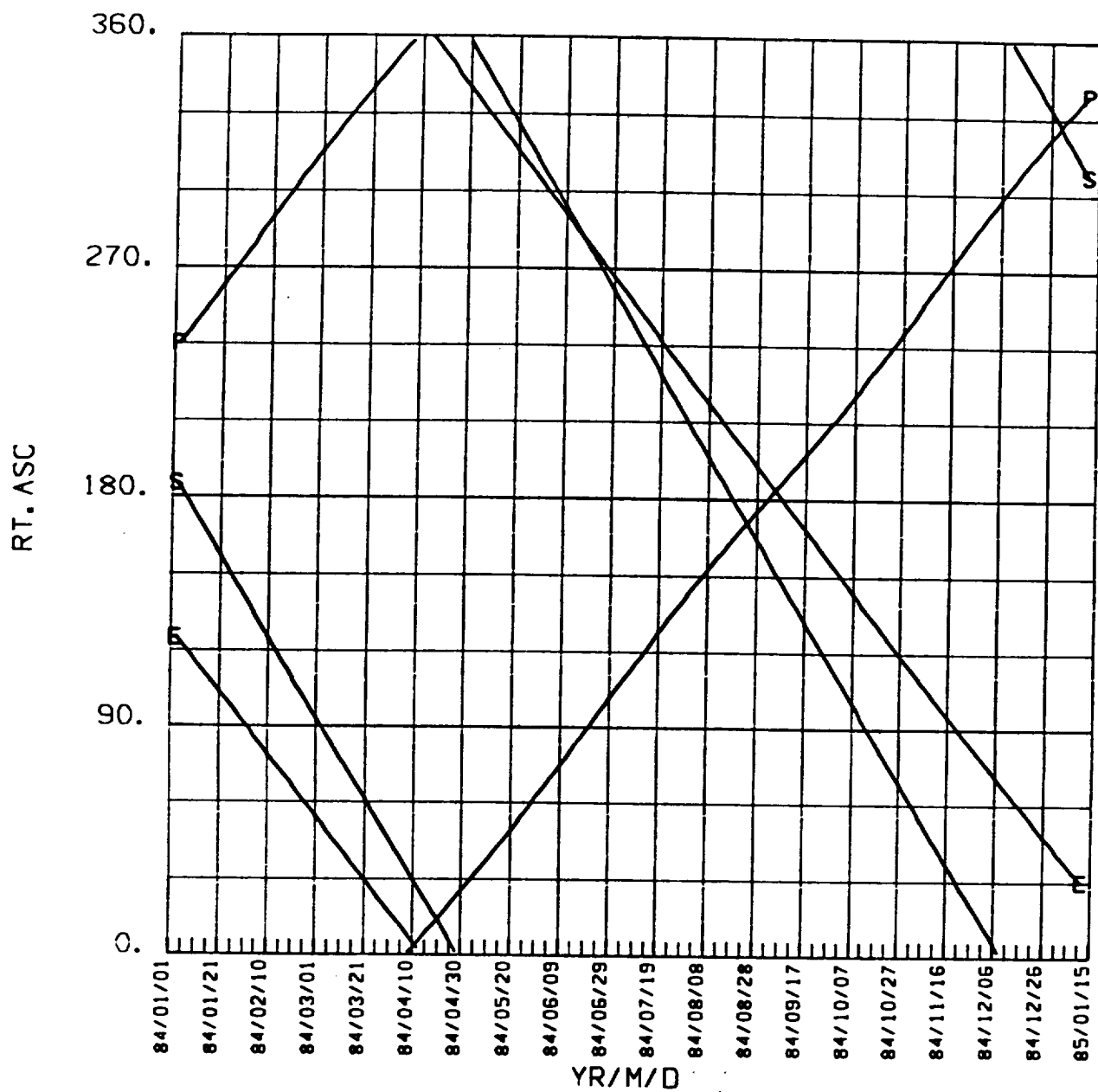


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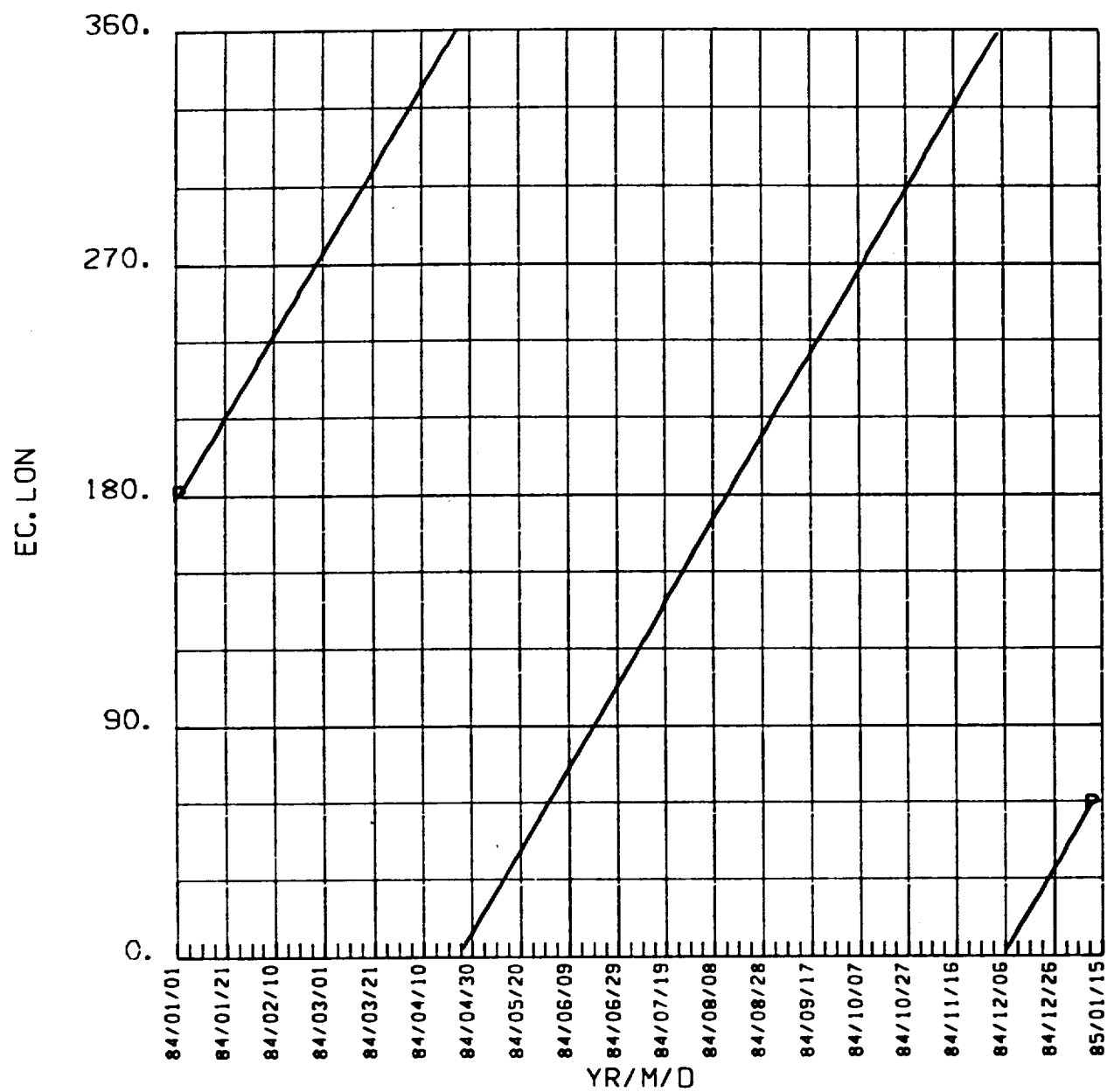


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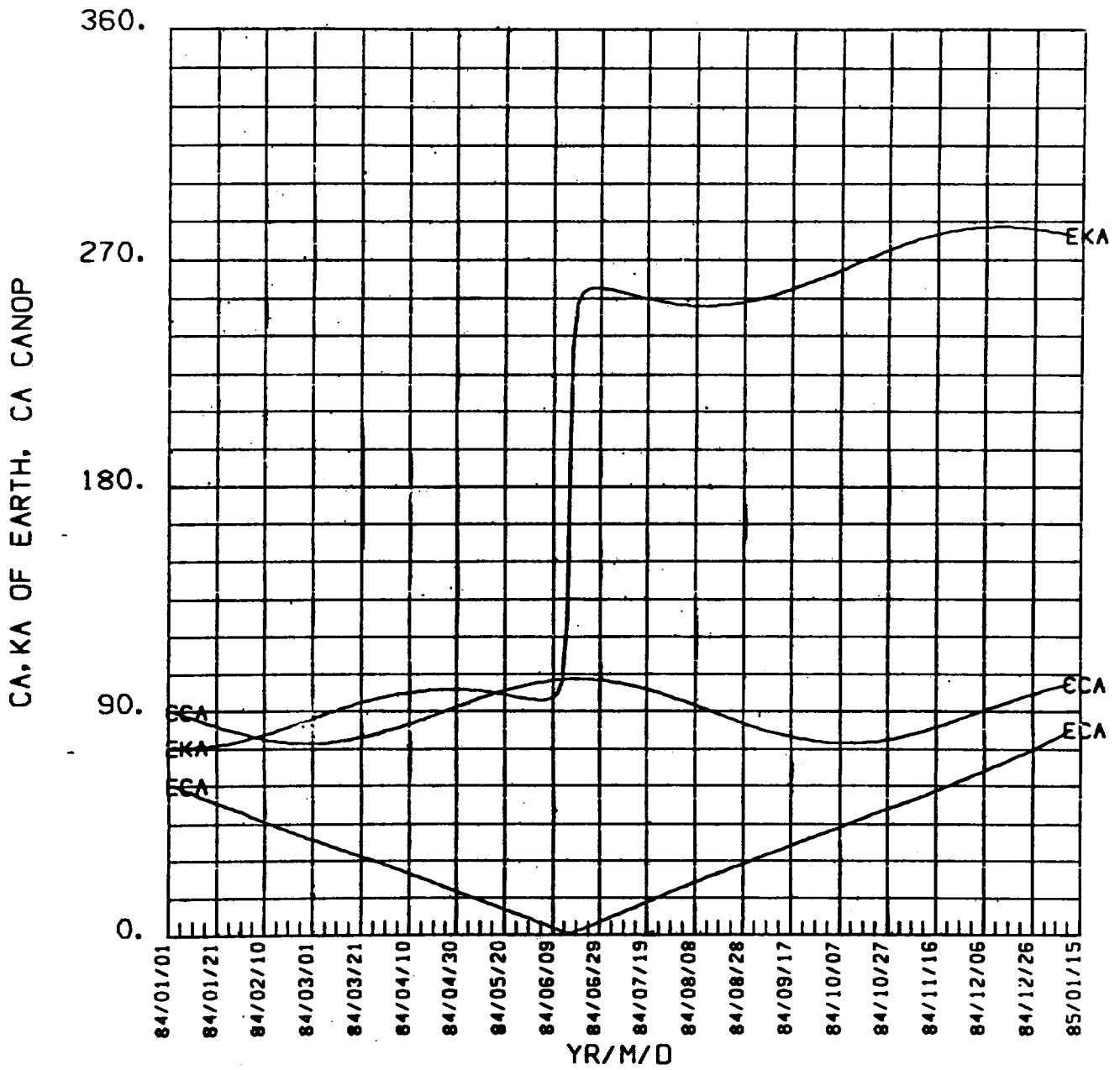


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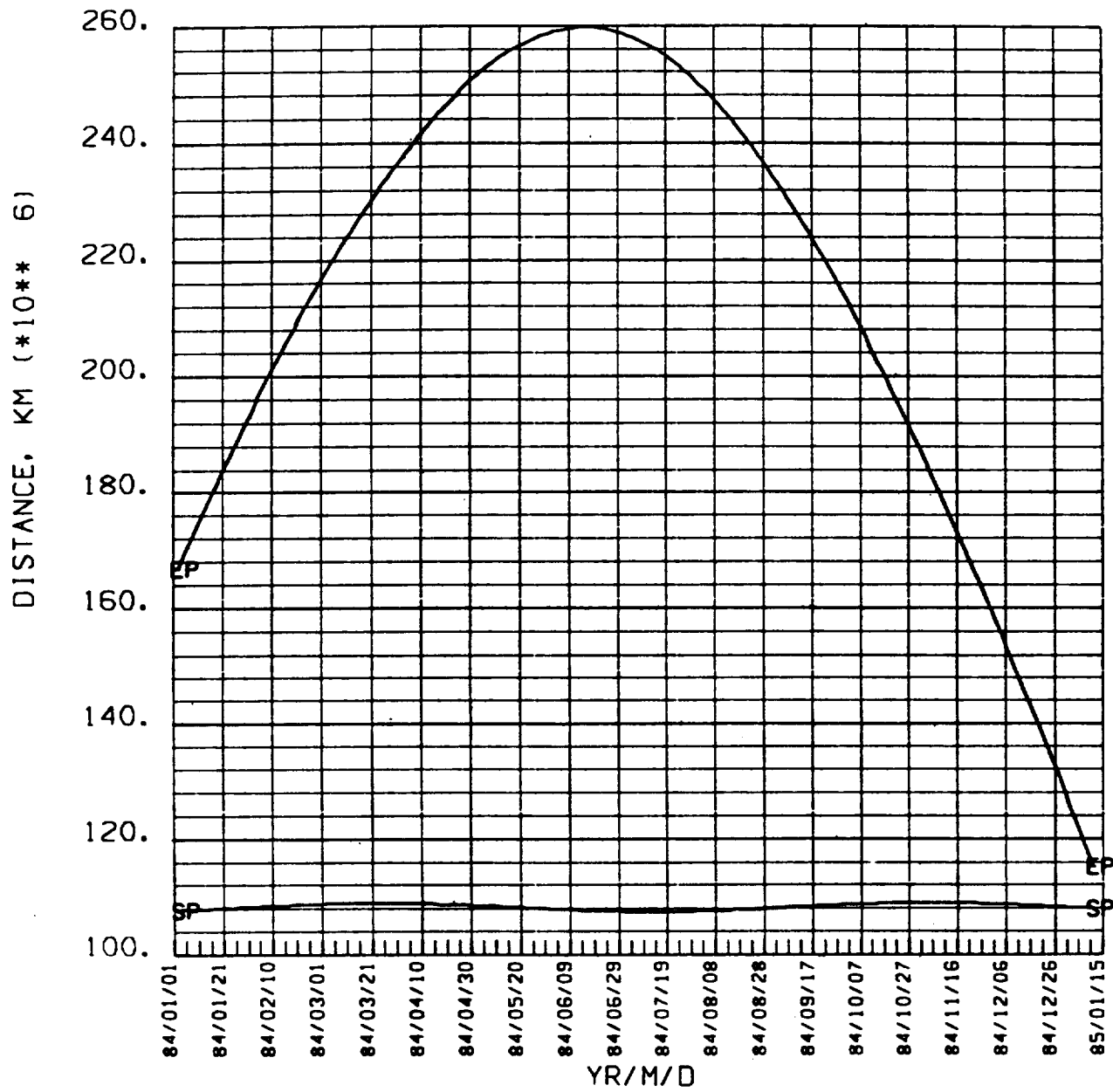
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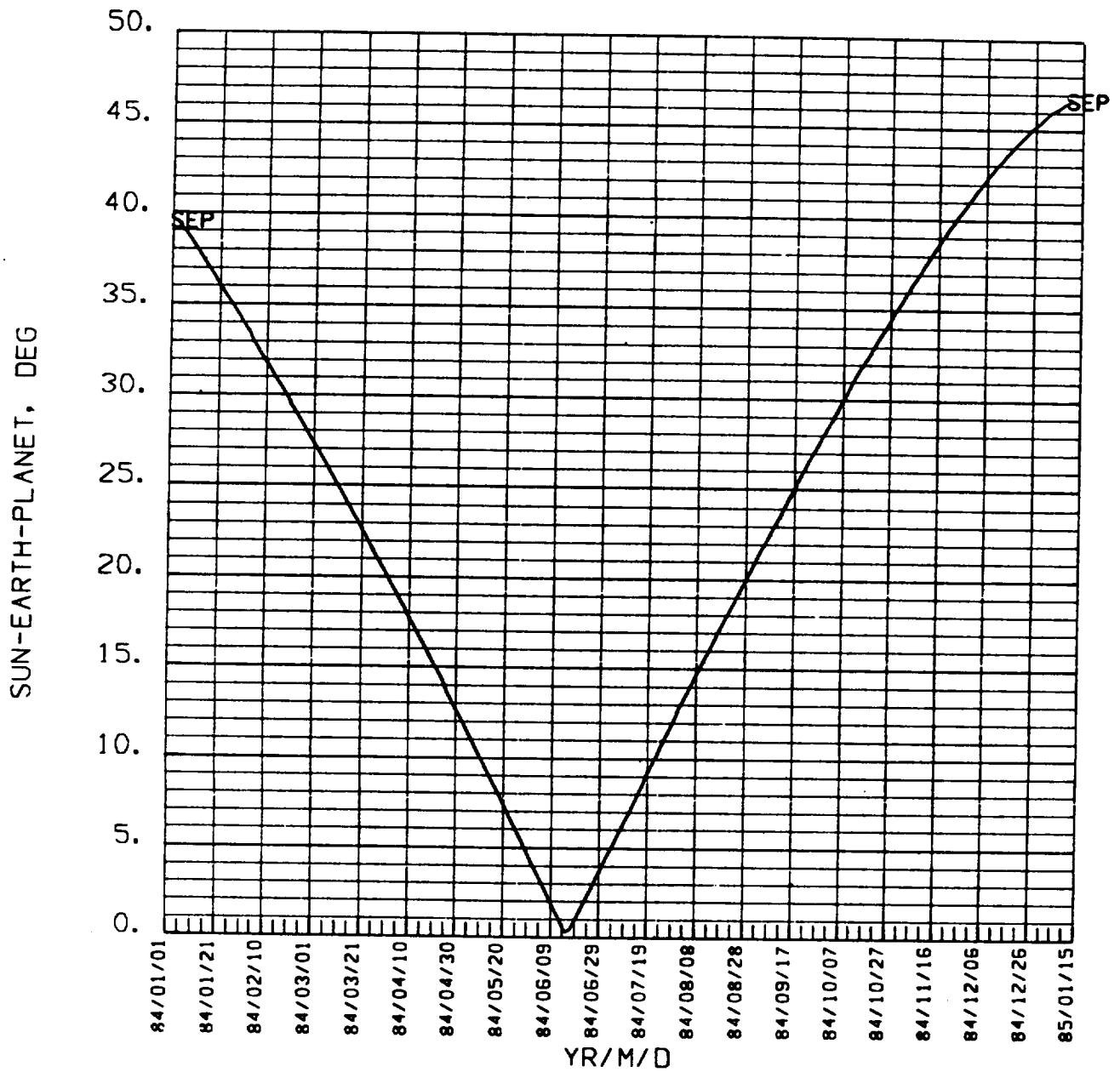
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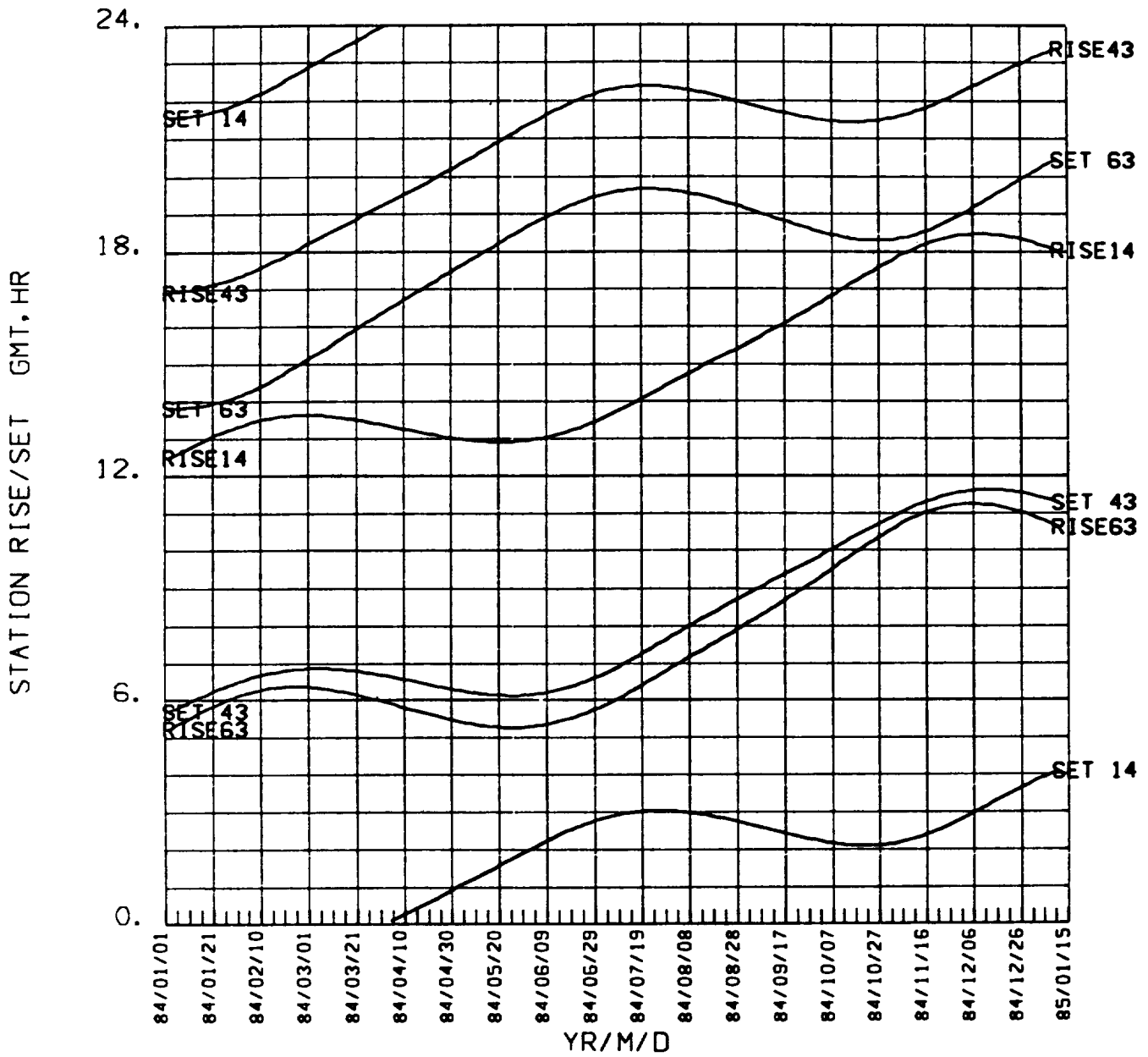


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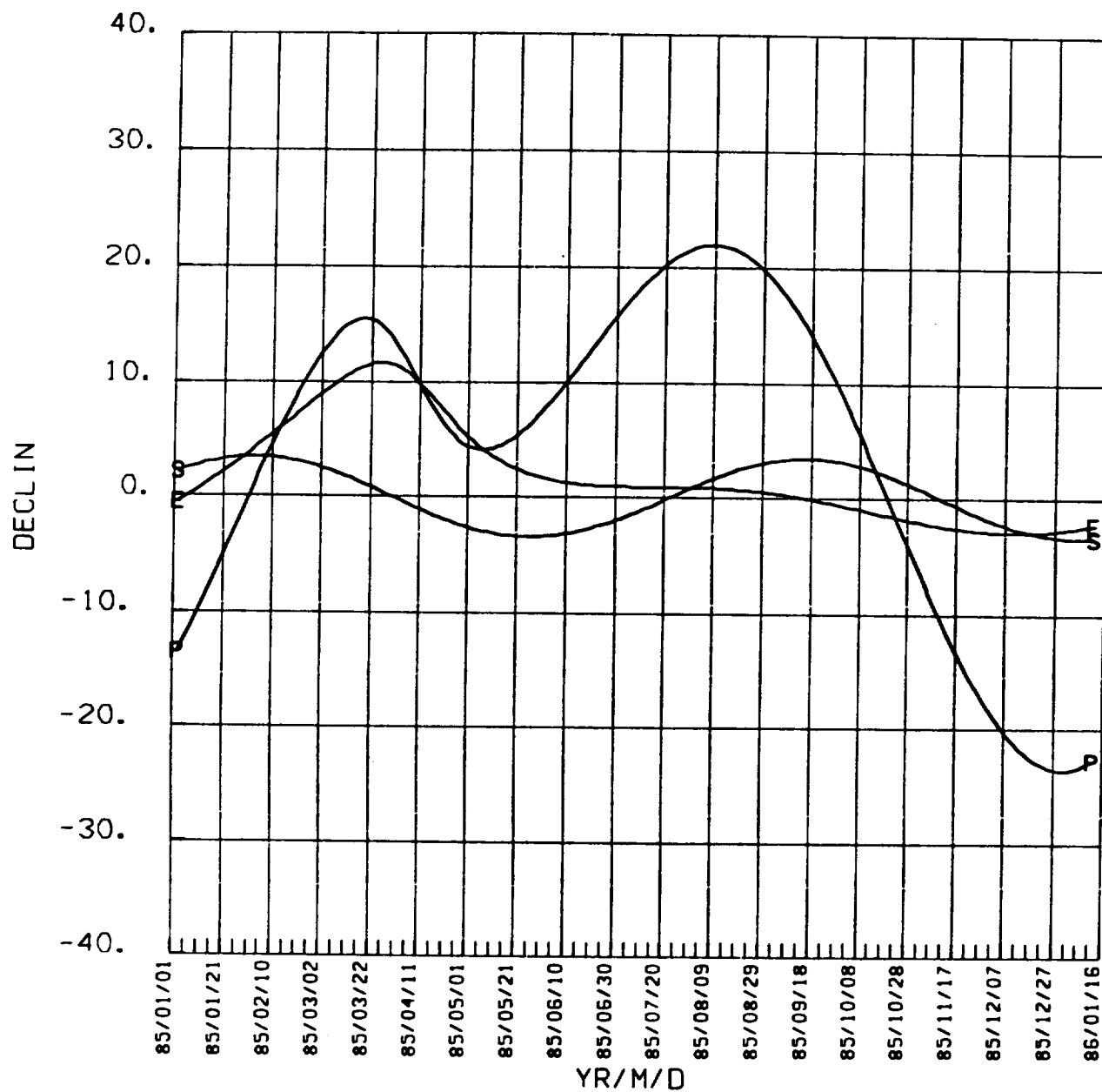
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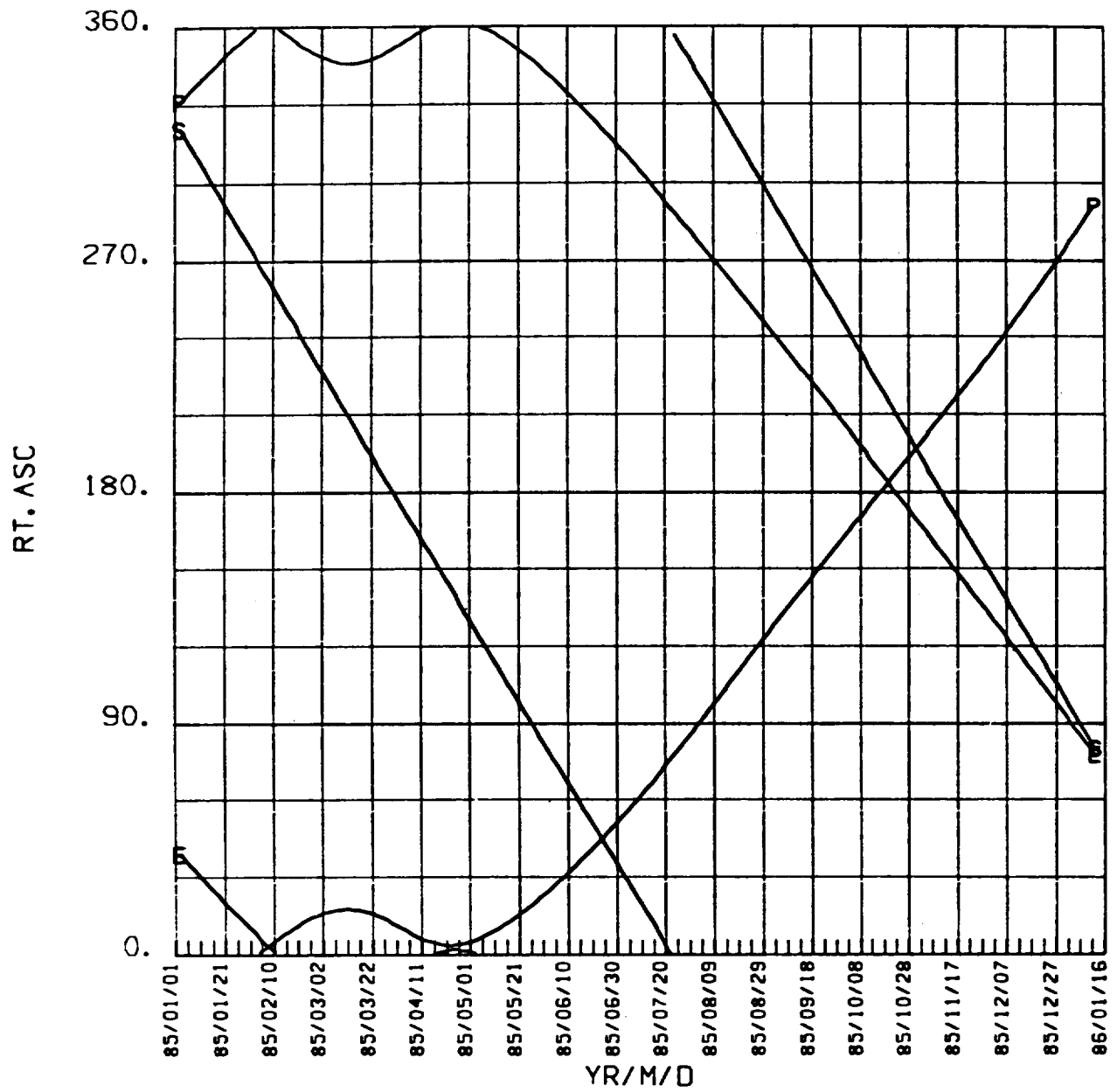


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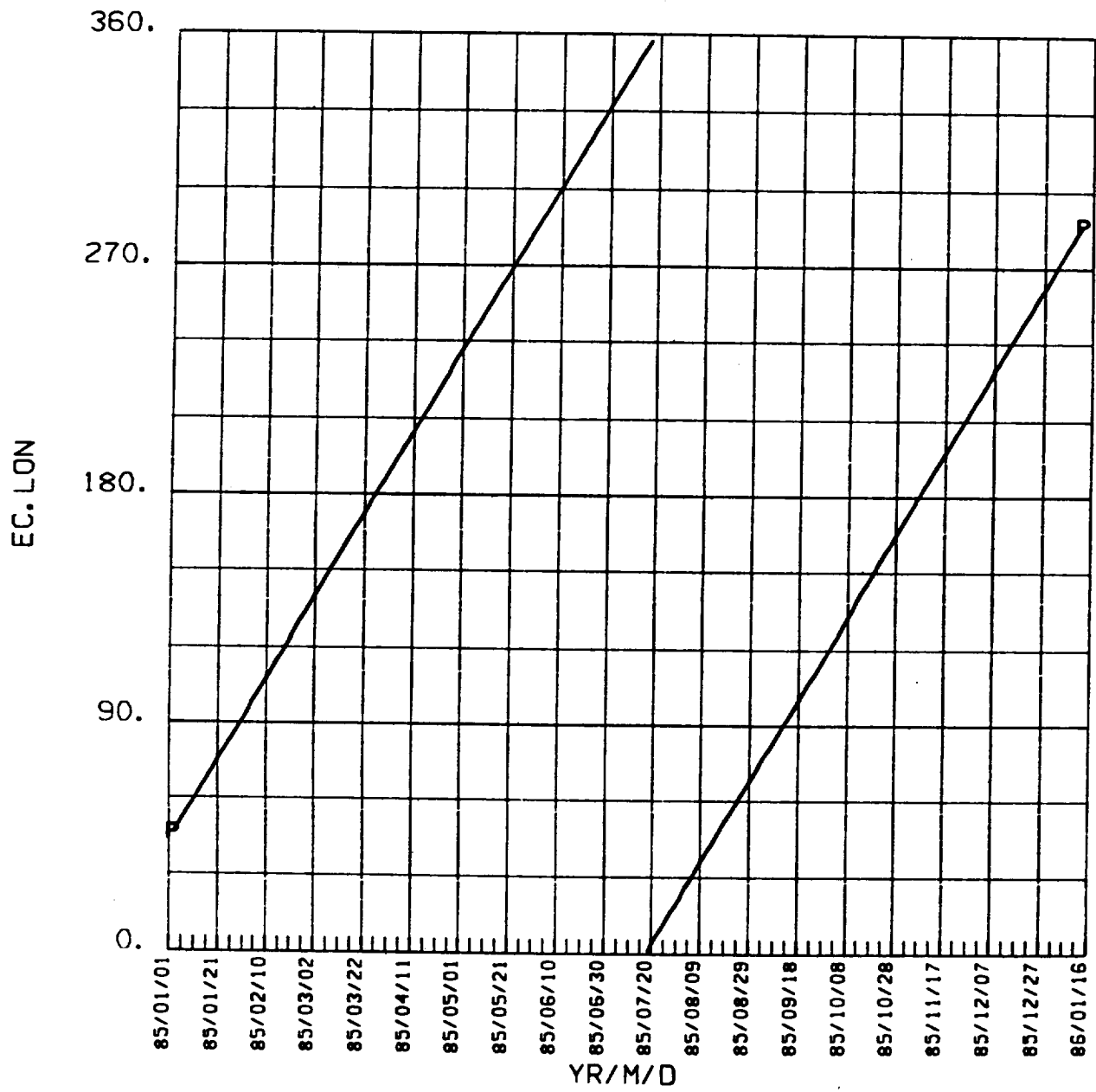
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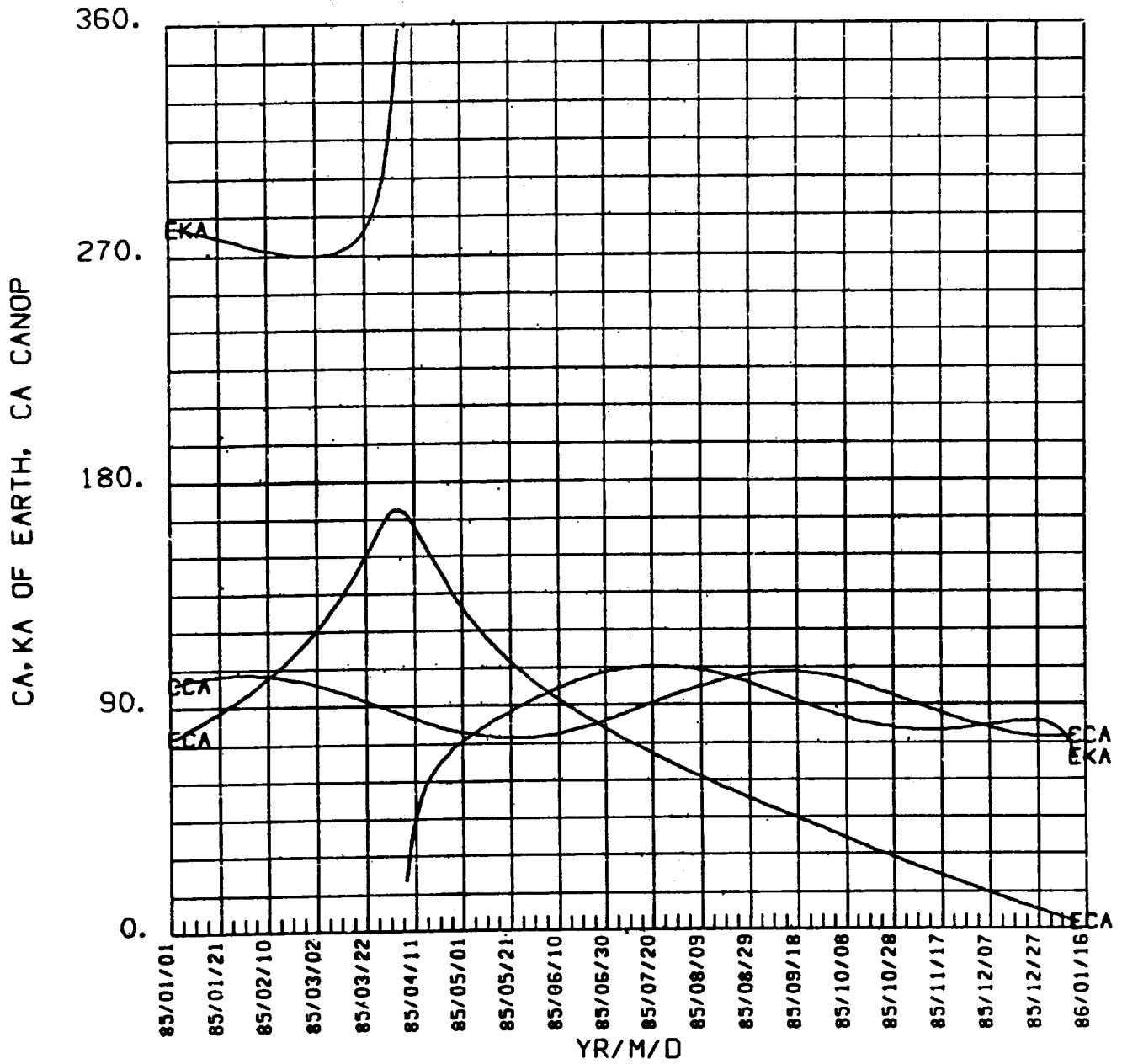
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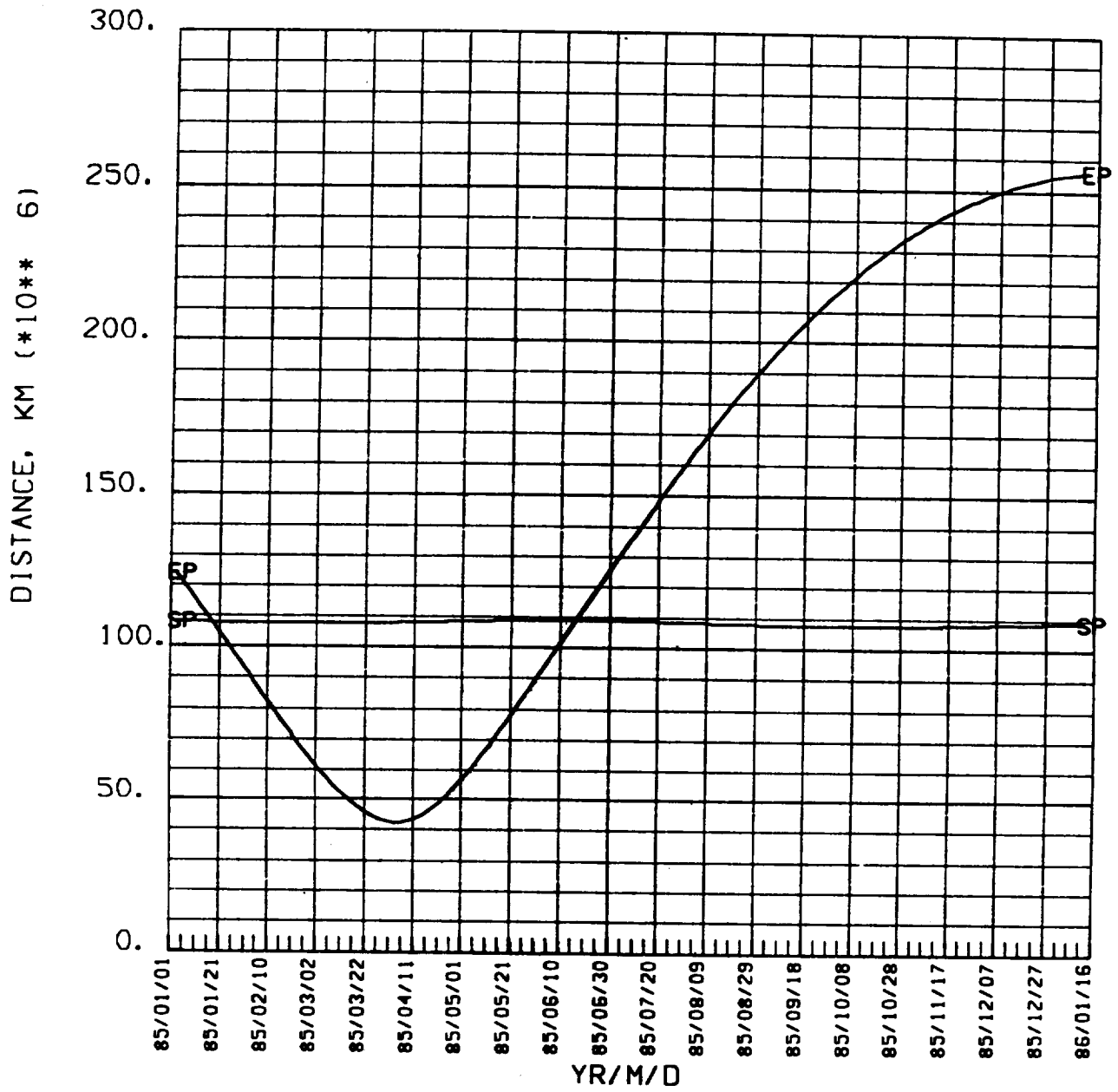
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VENUS

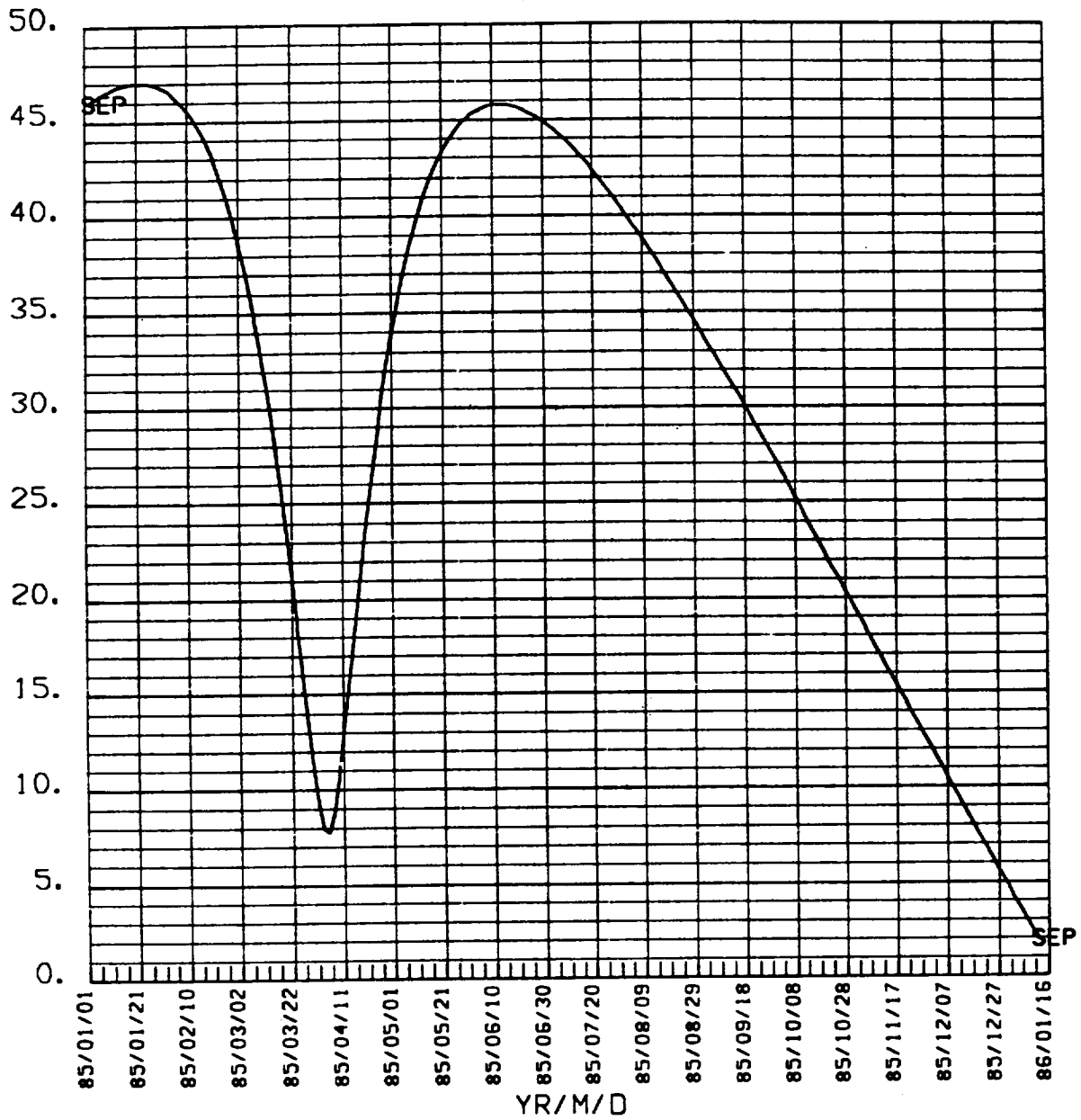
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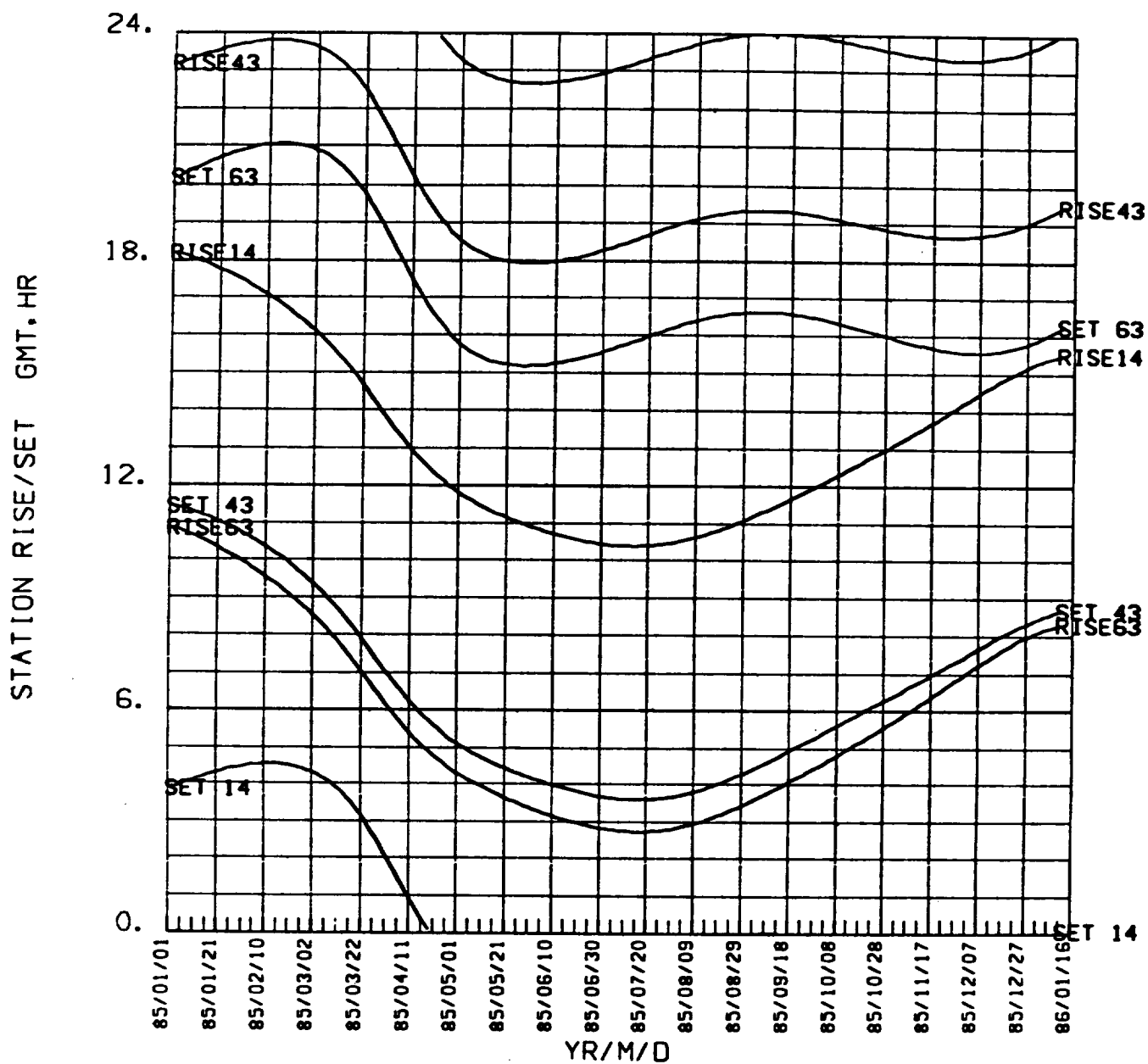
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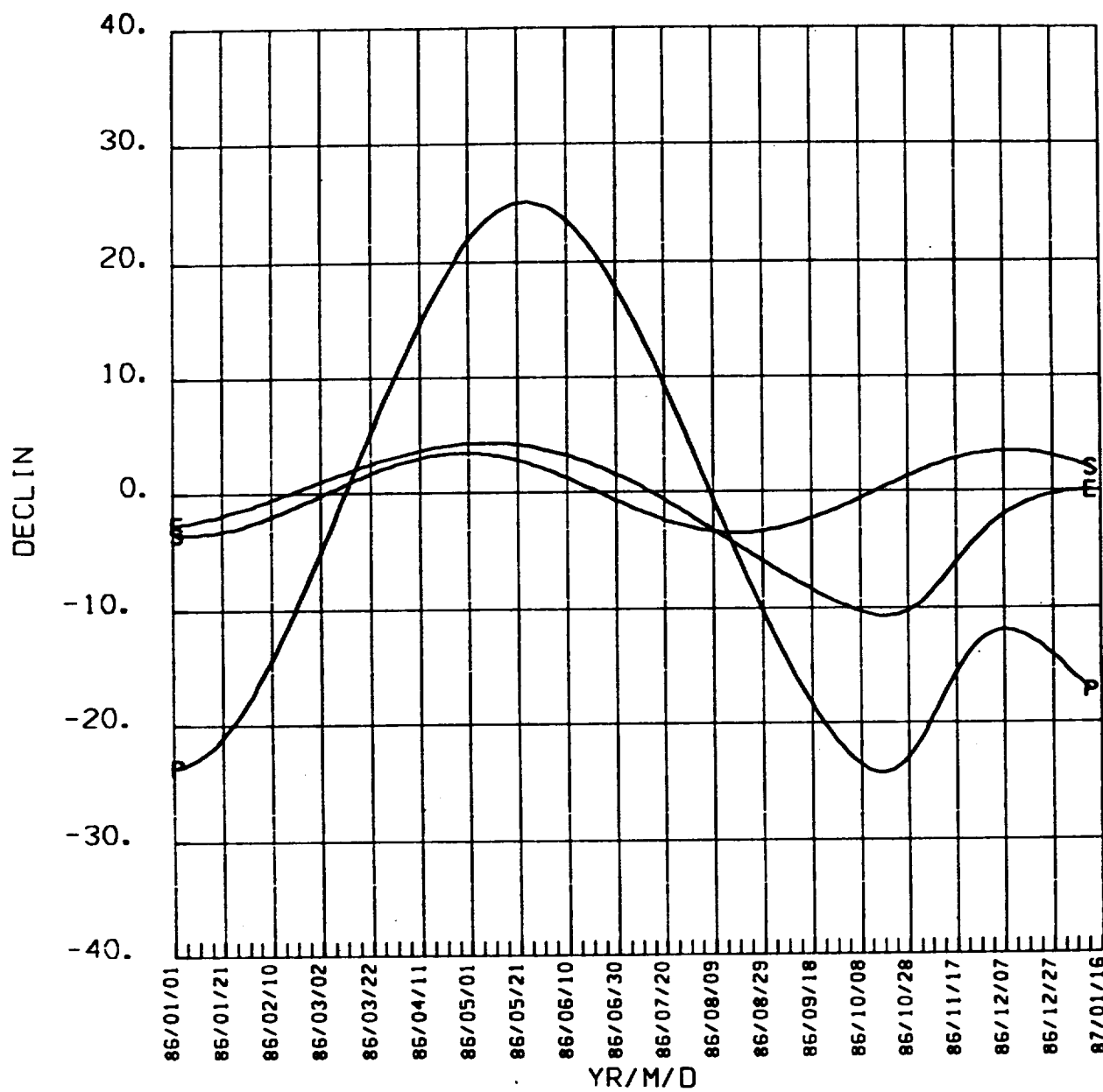
SUN-EARTH-PLANET, DEG



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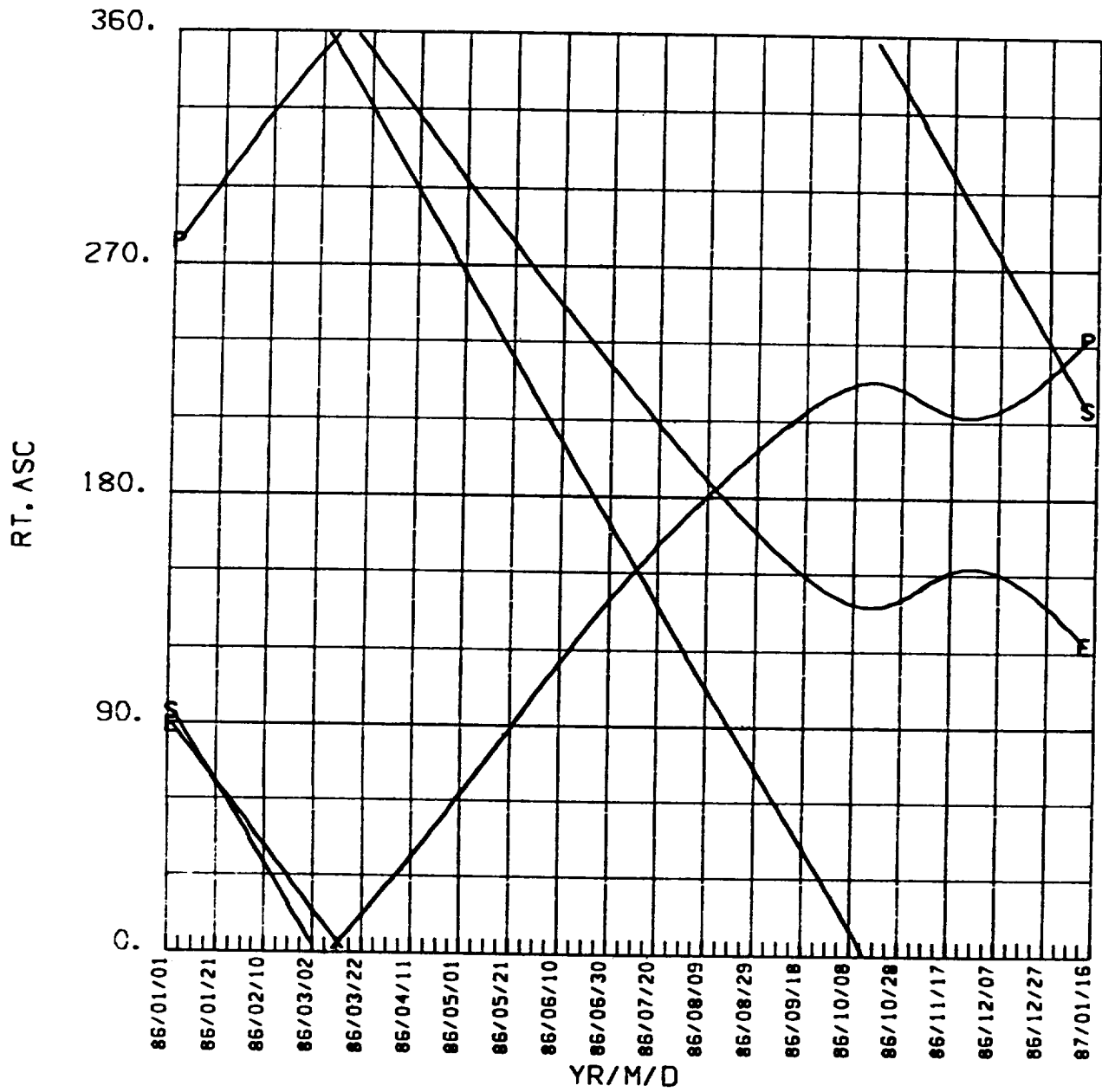


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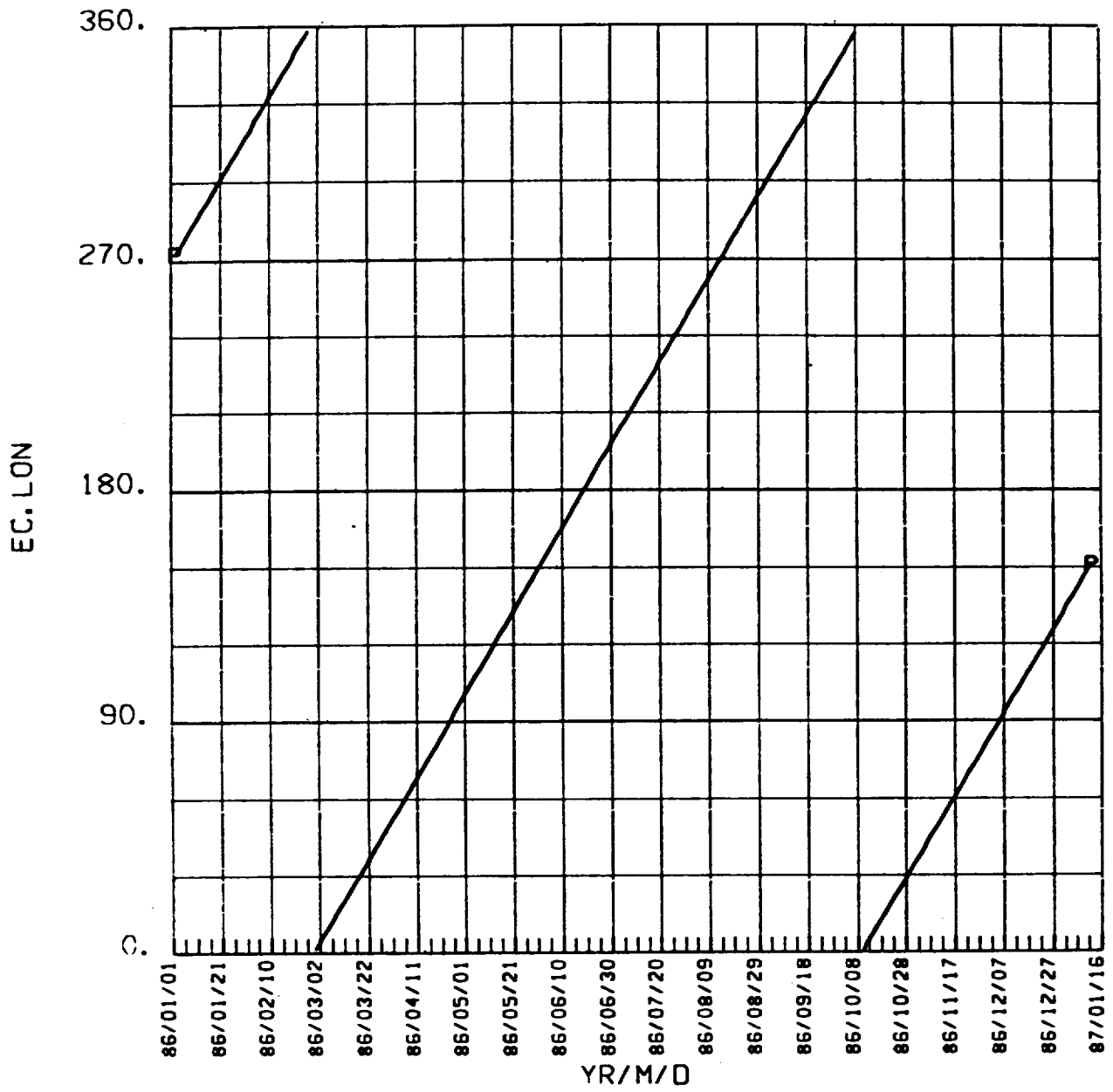
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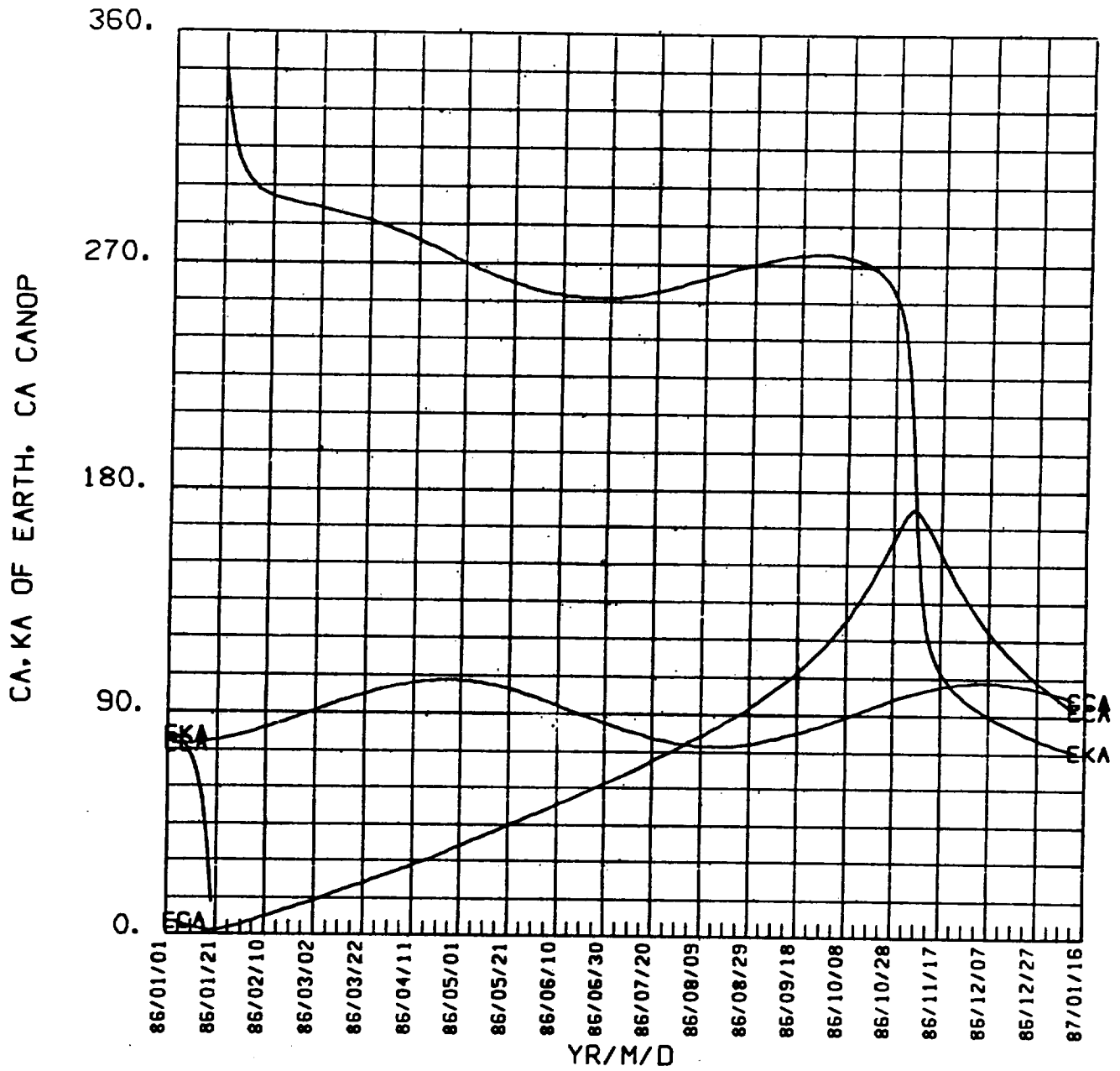
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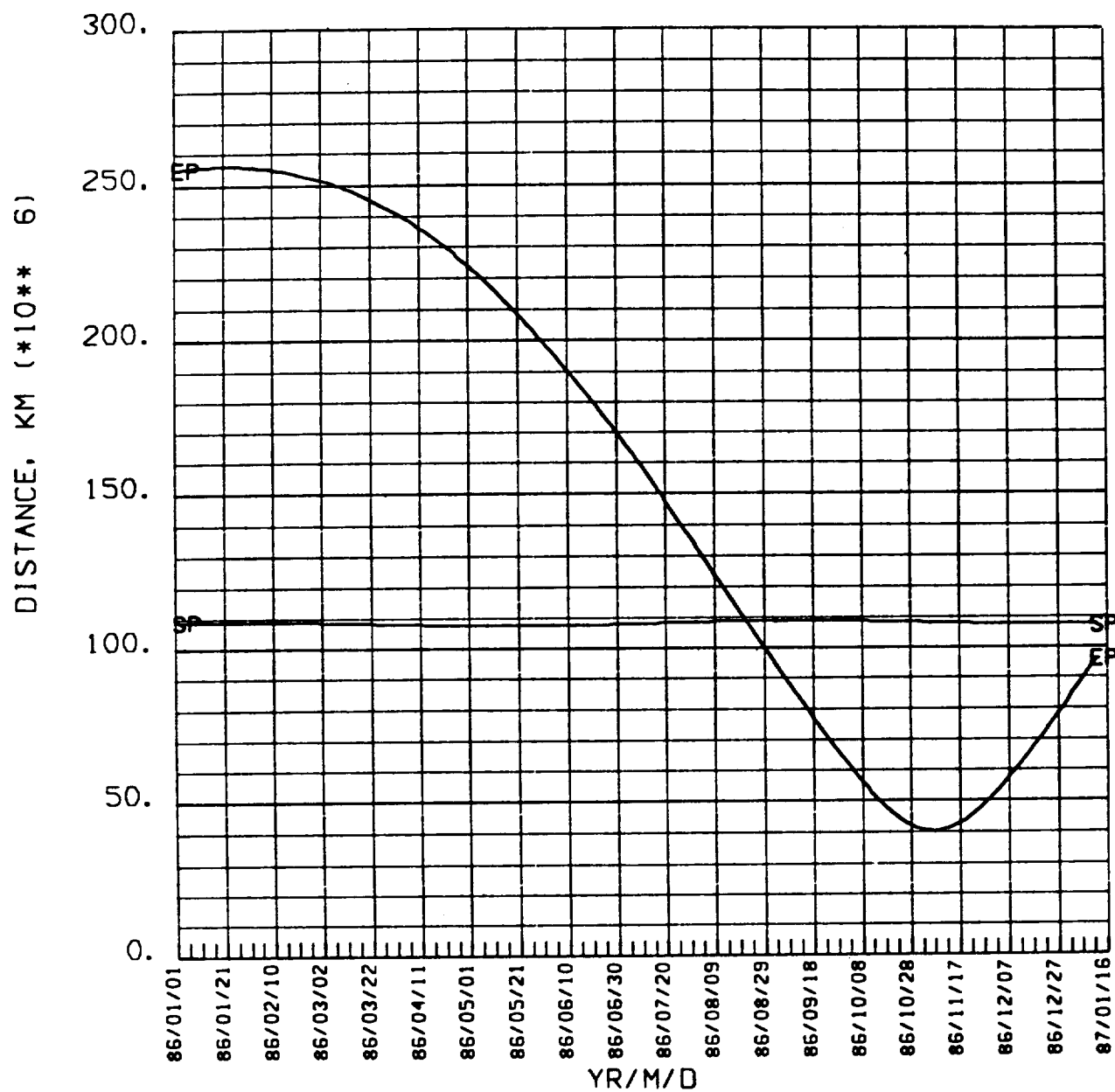
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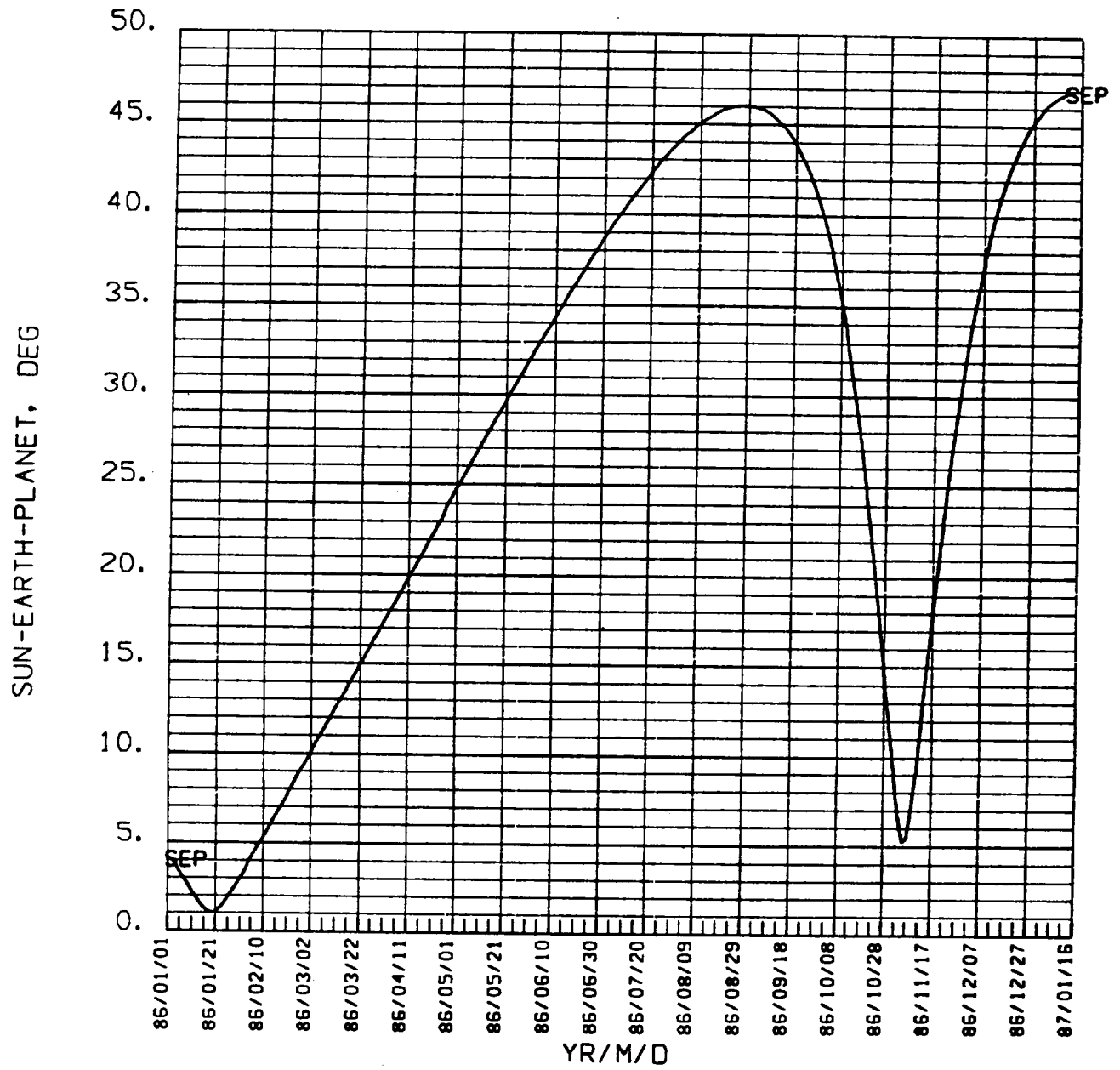


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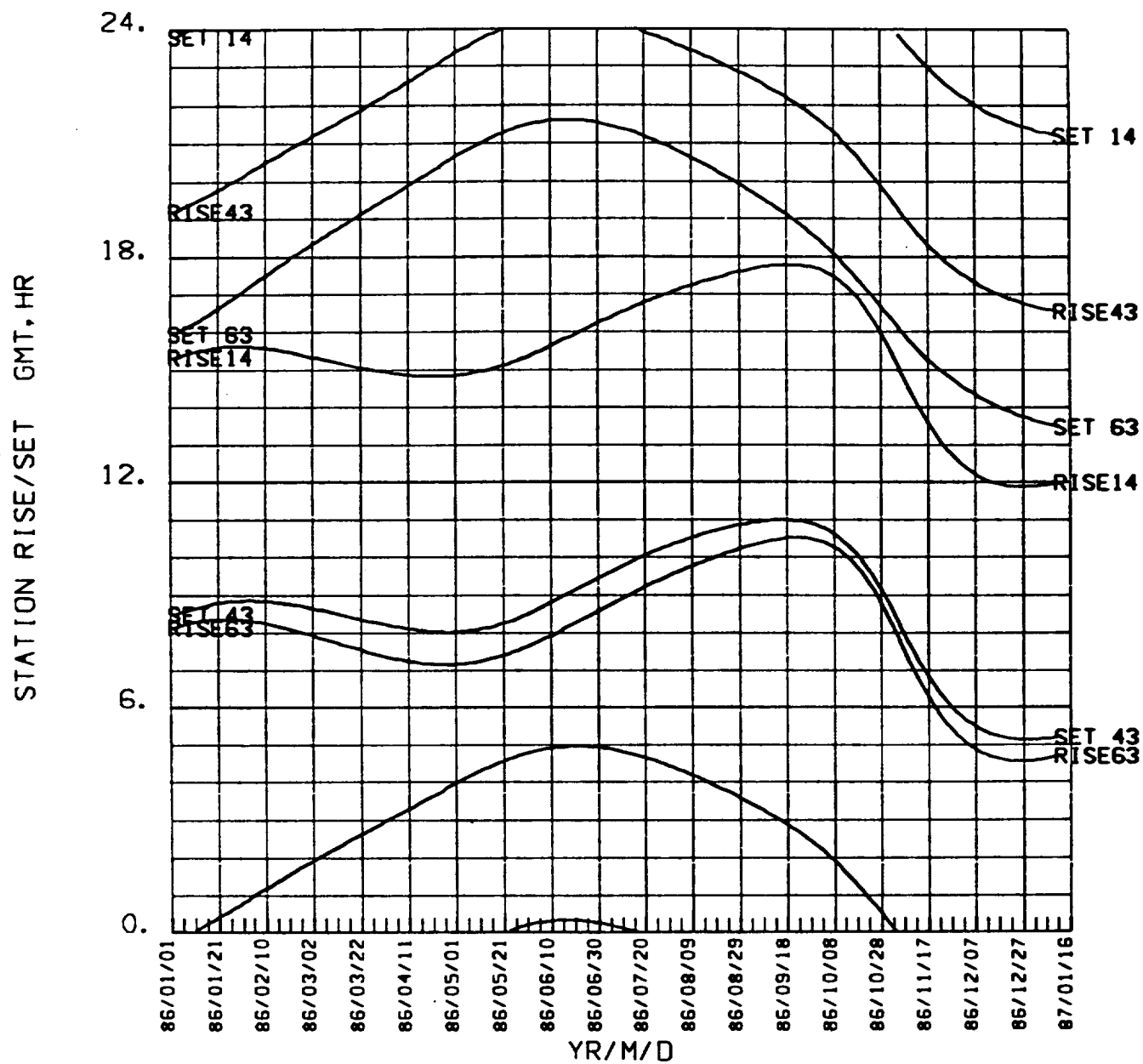


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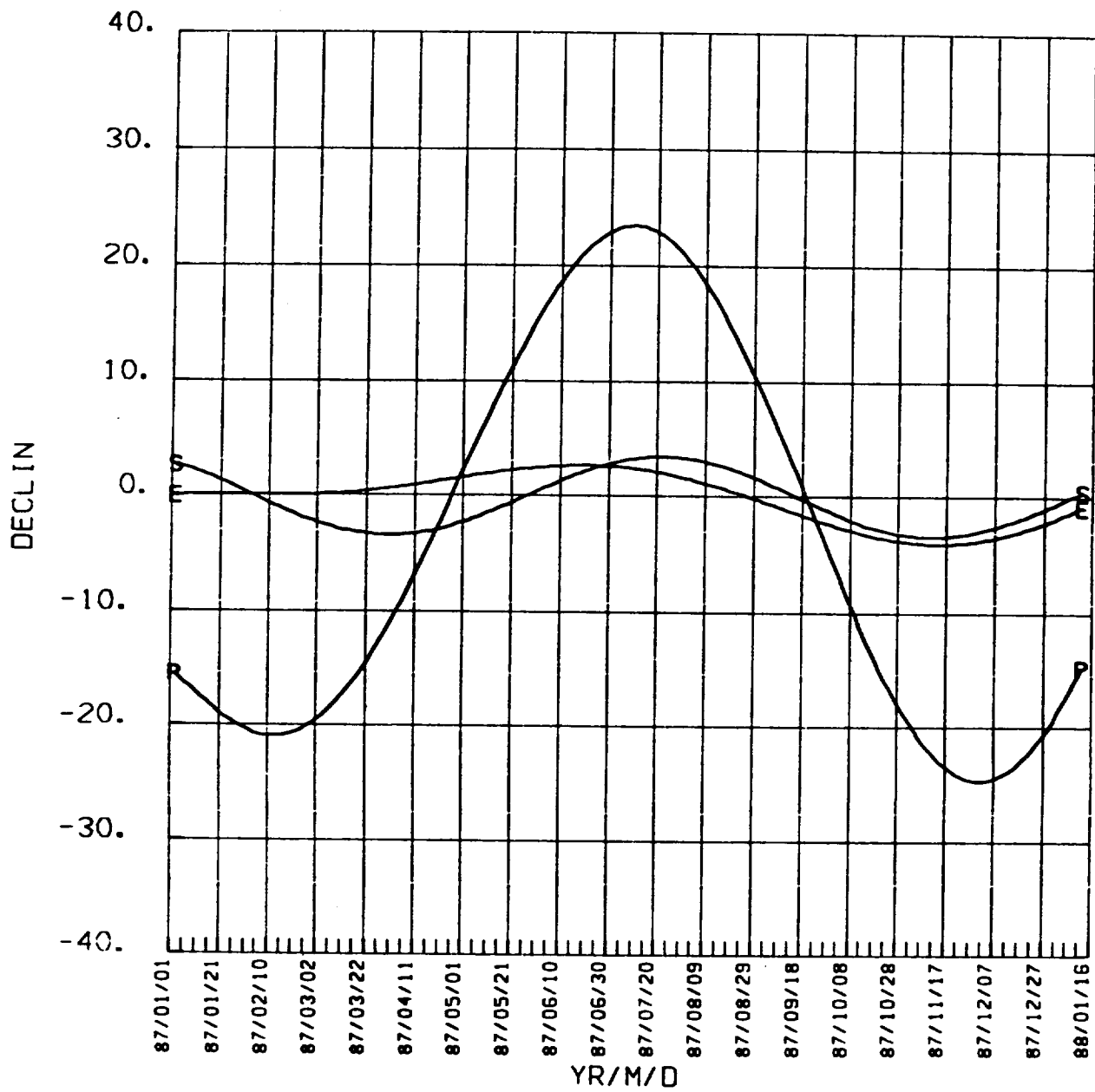


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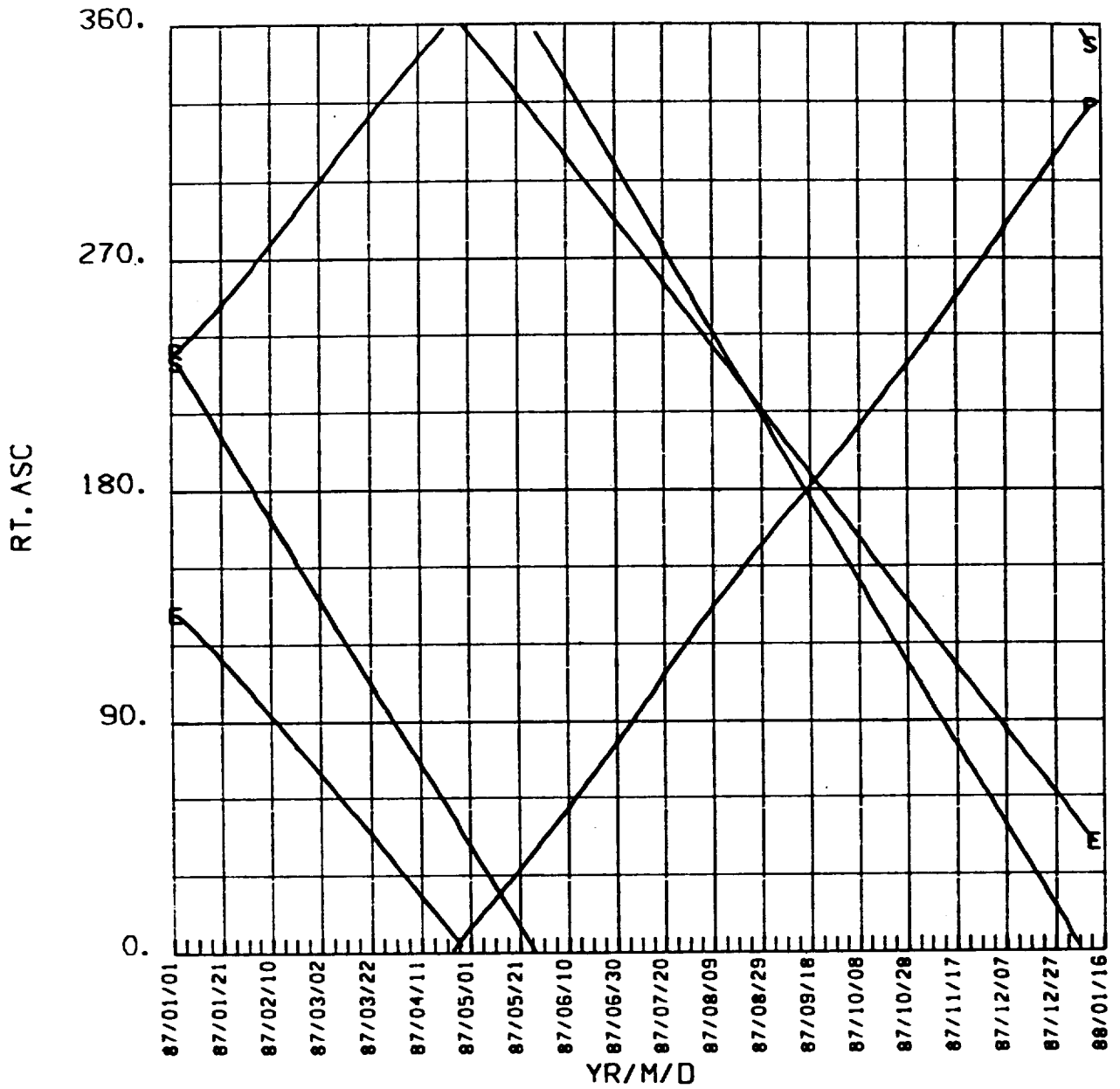


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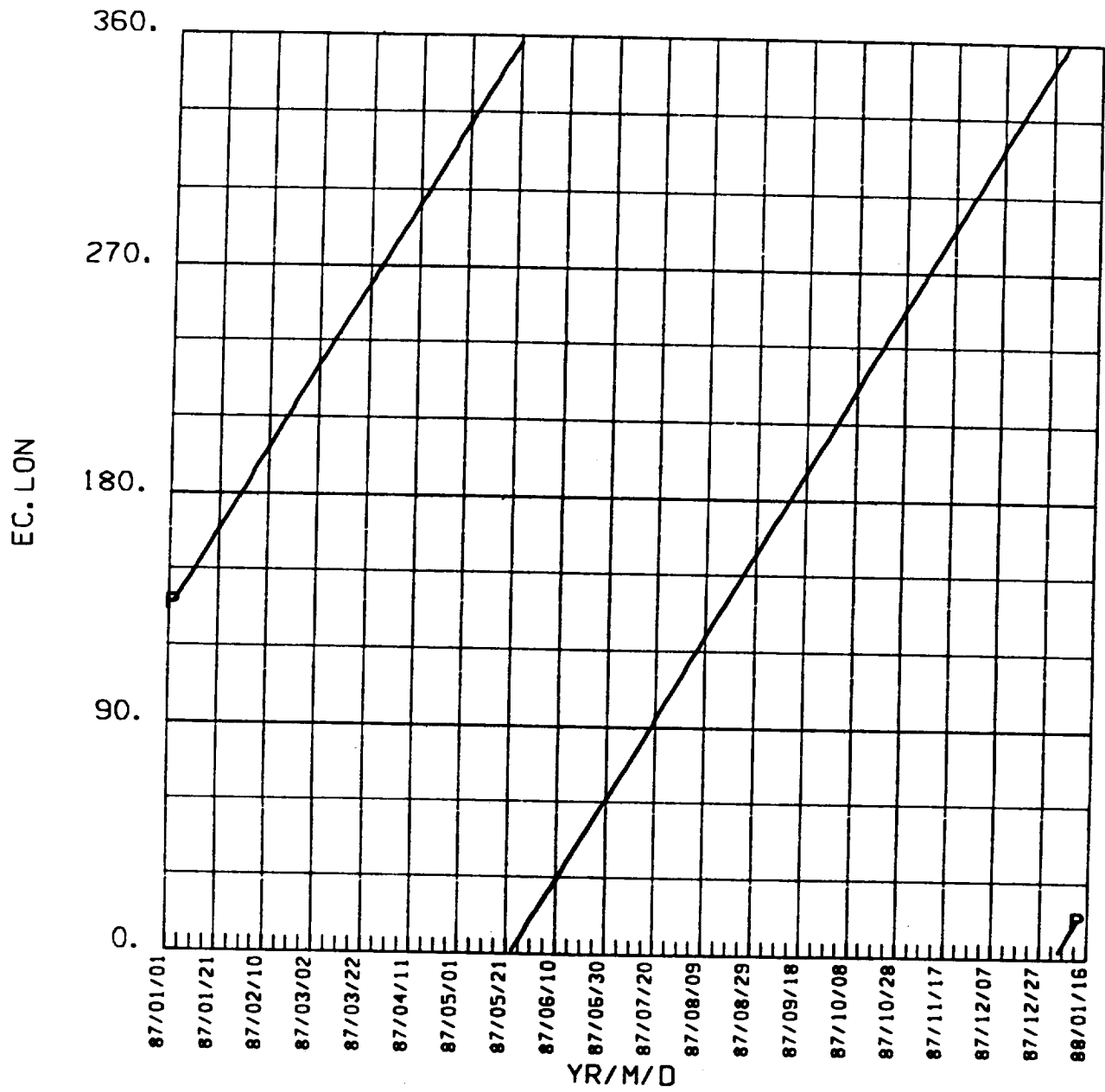


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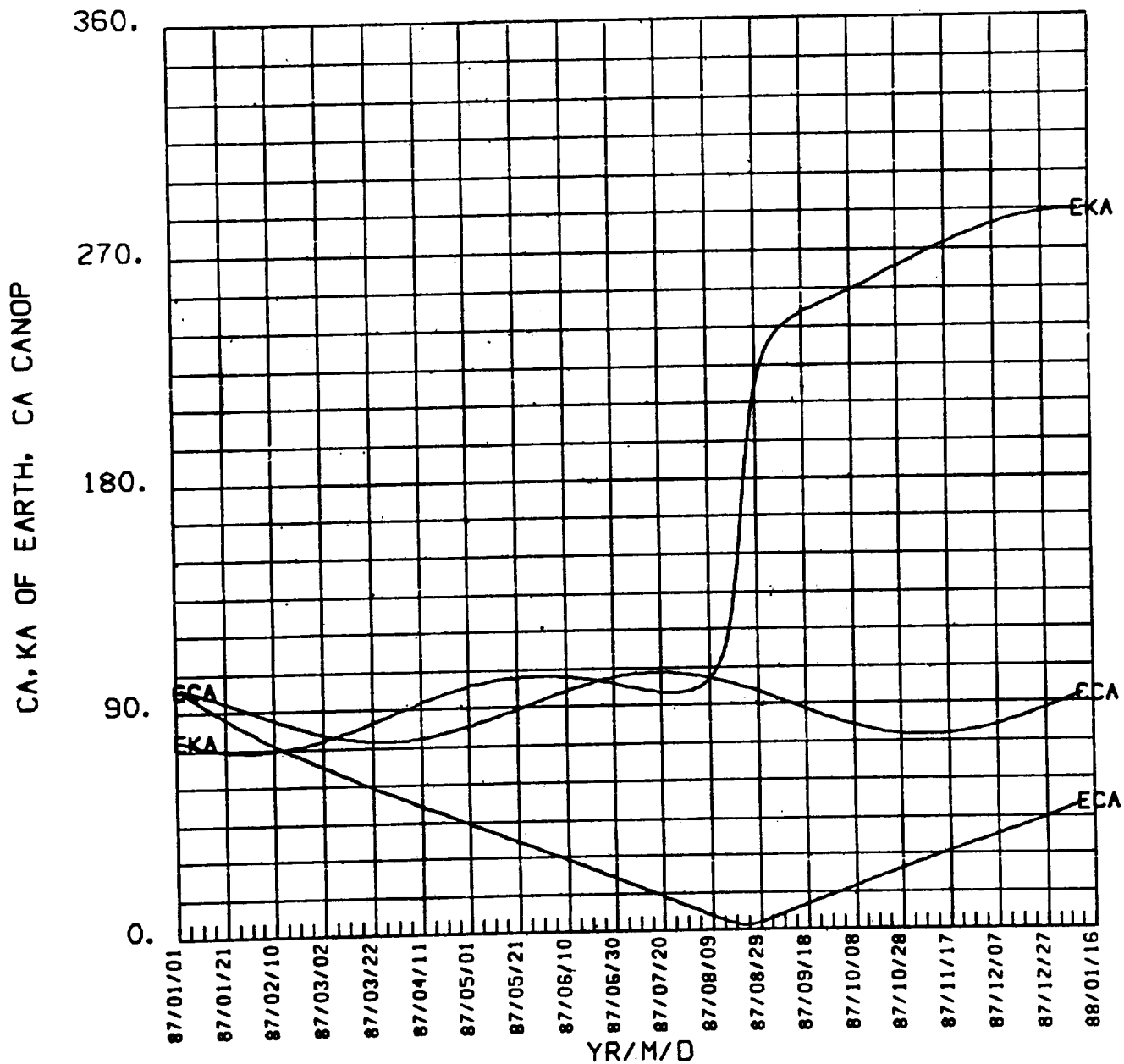


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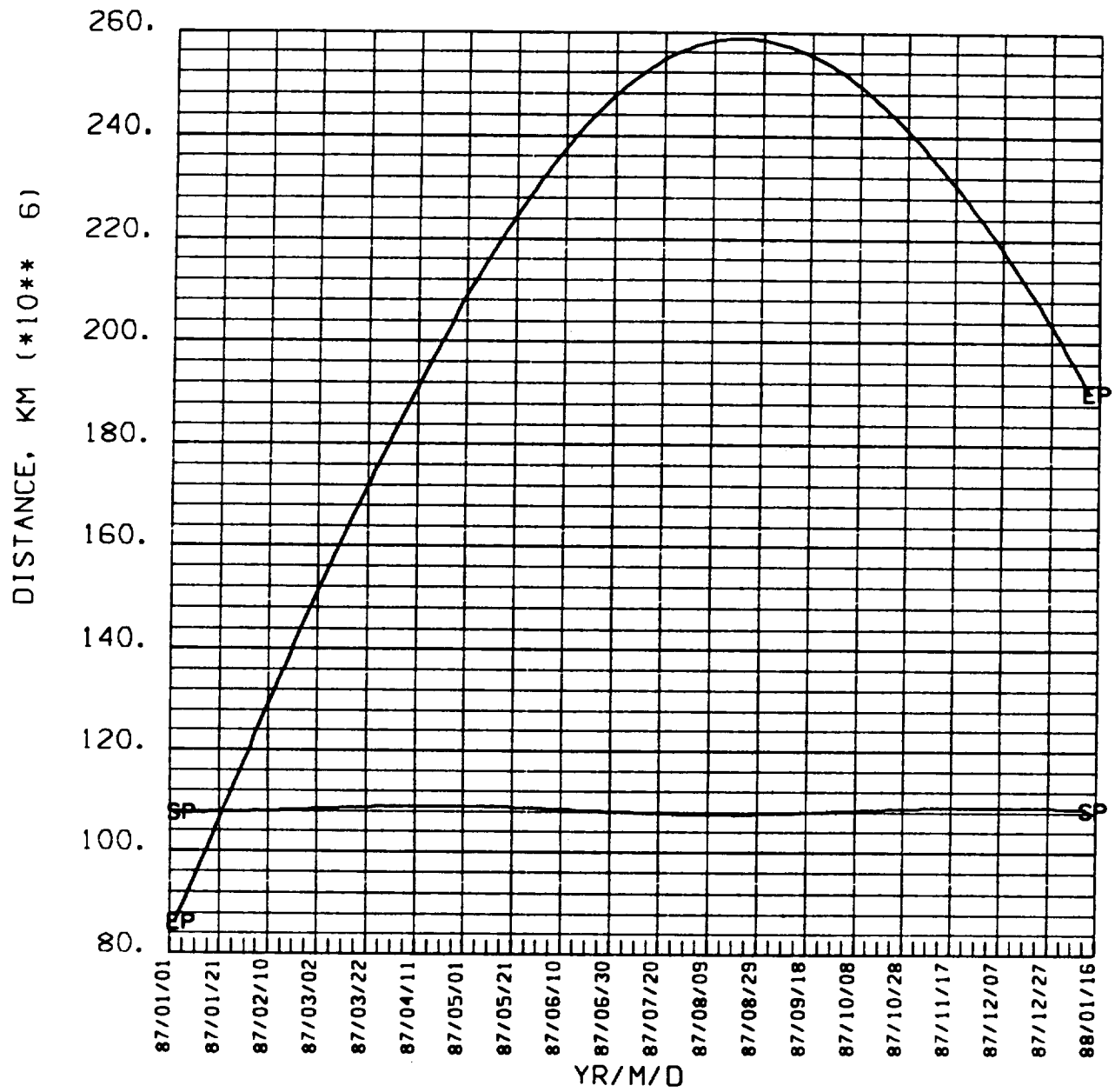
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1987



VENUS

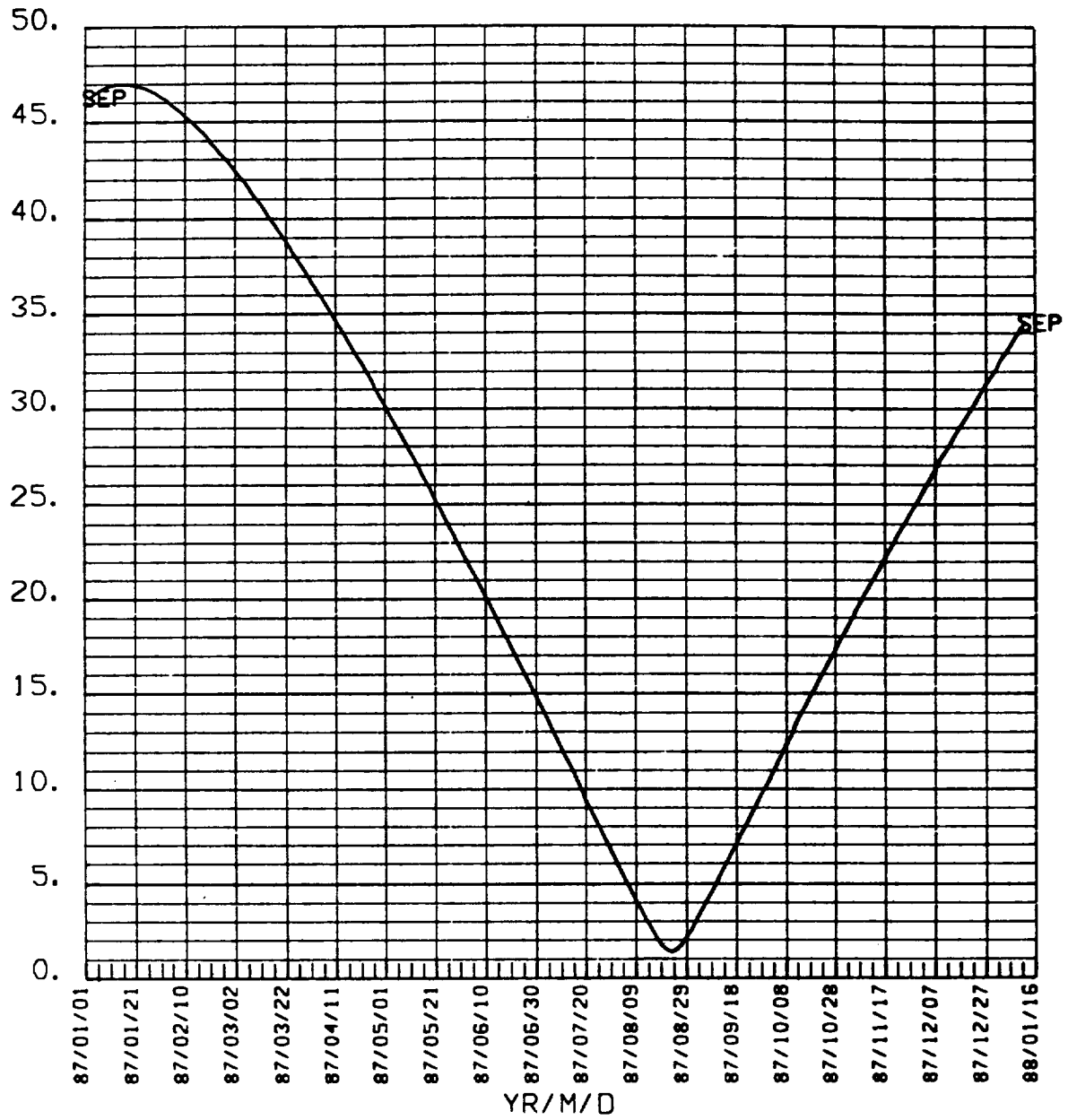
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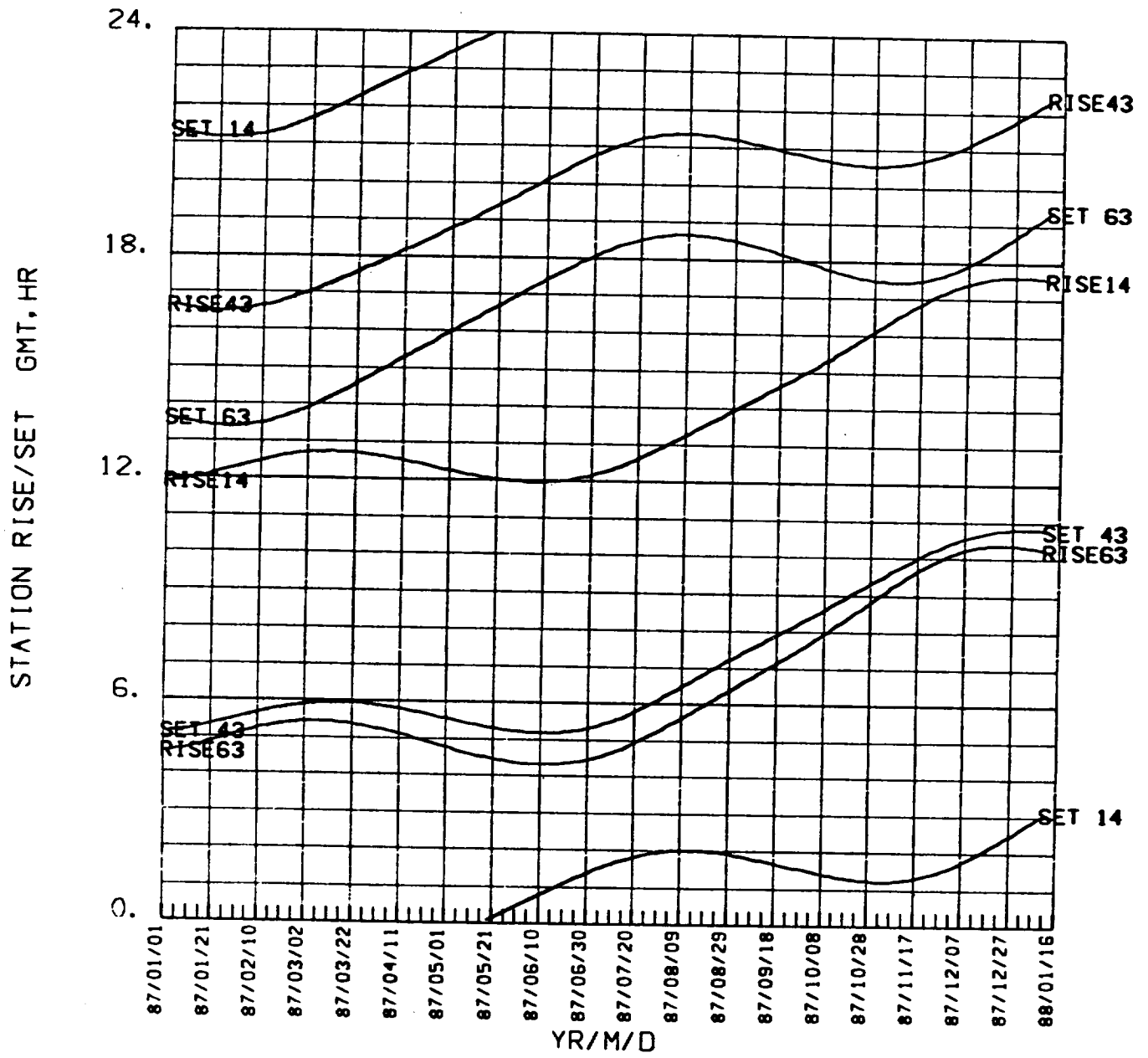
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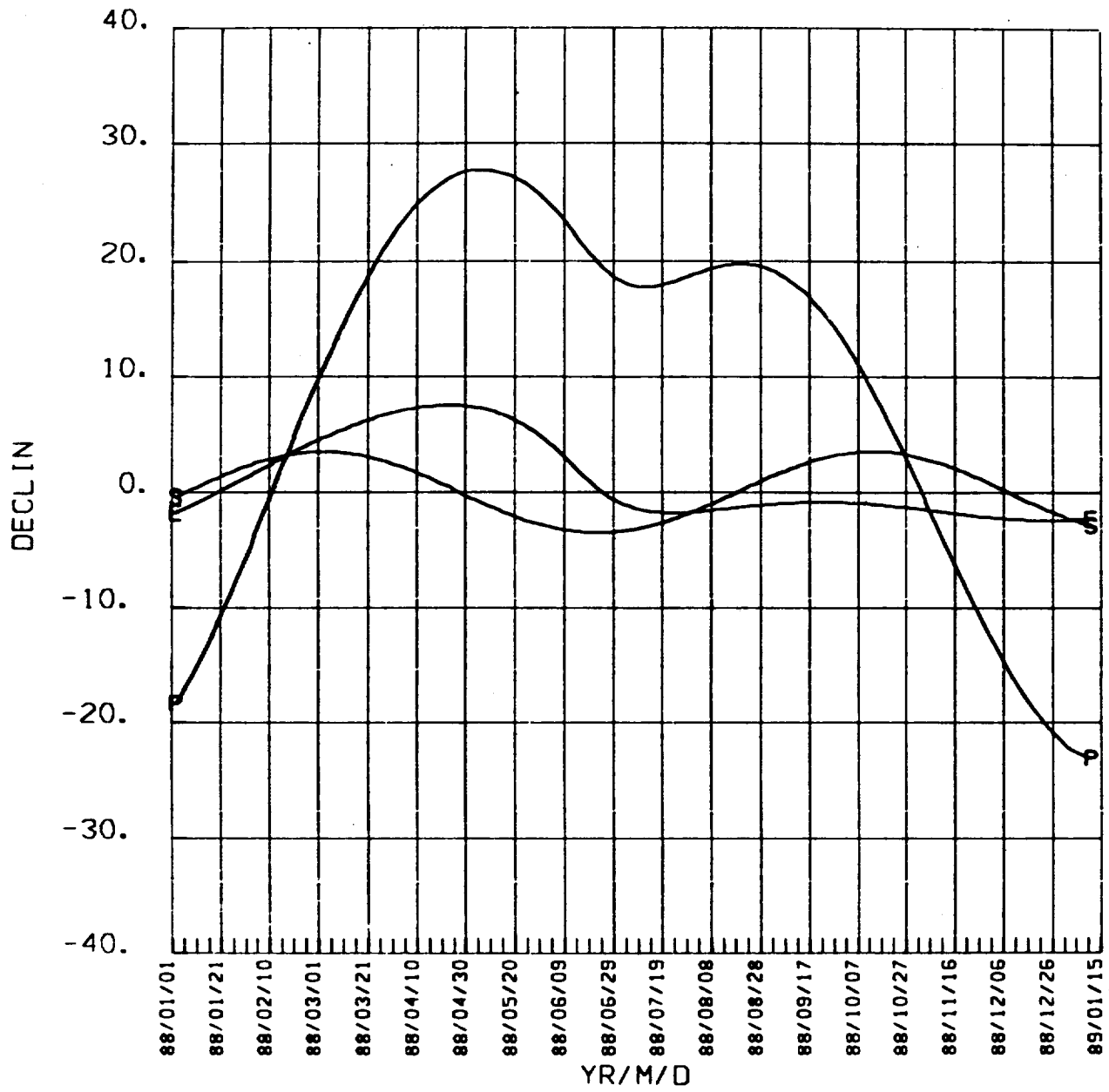
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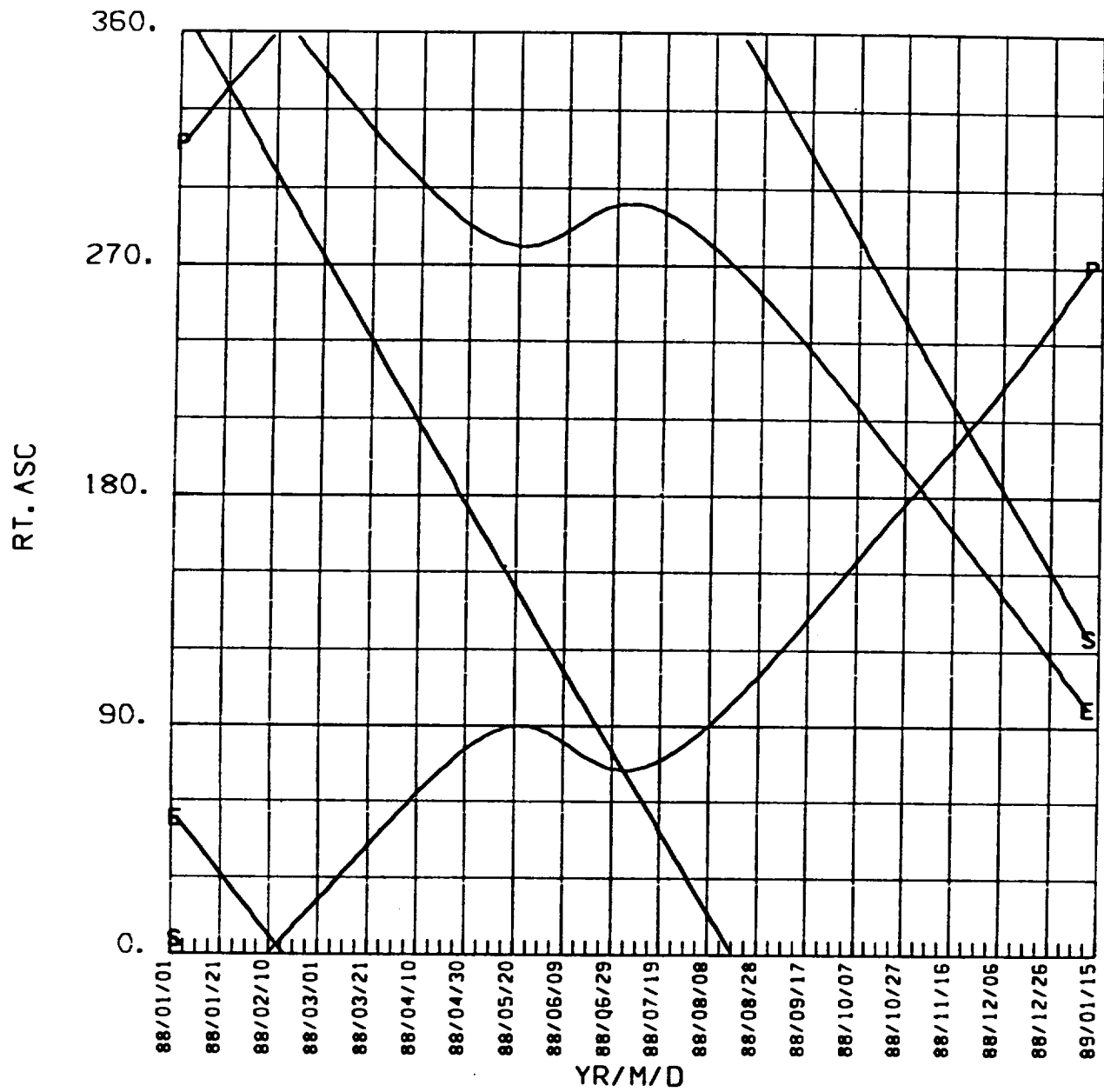
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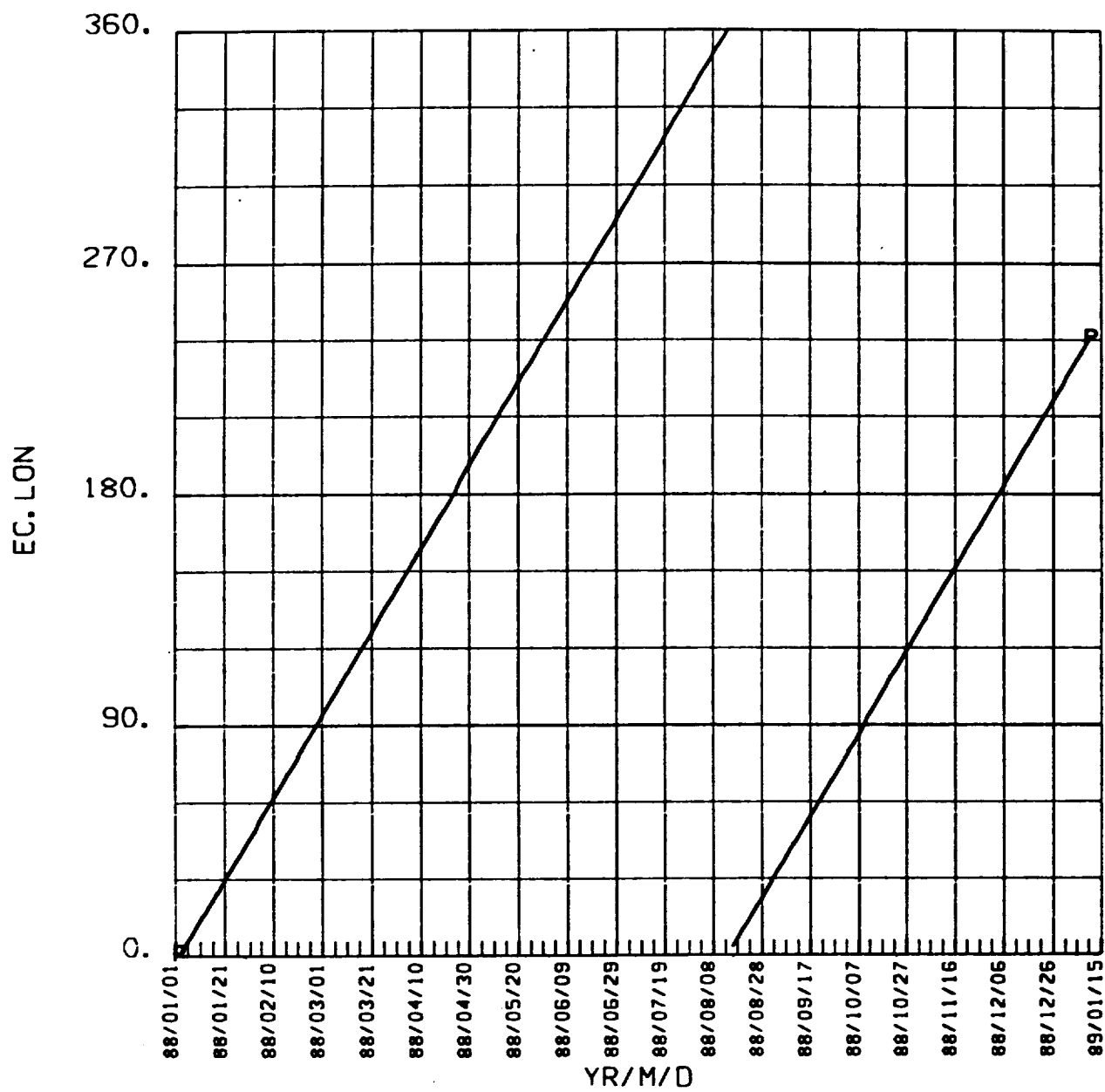
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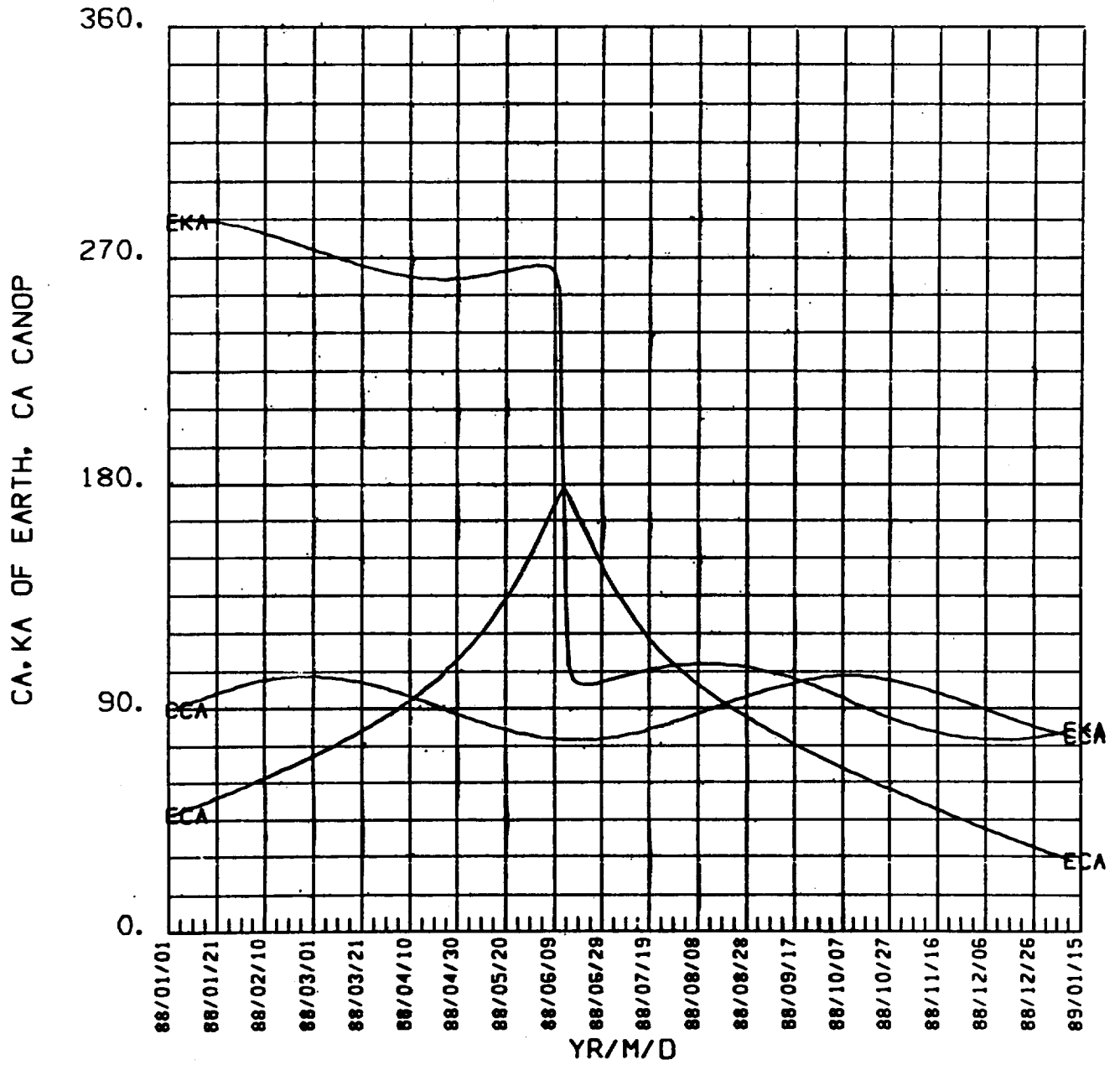
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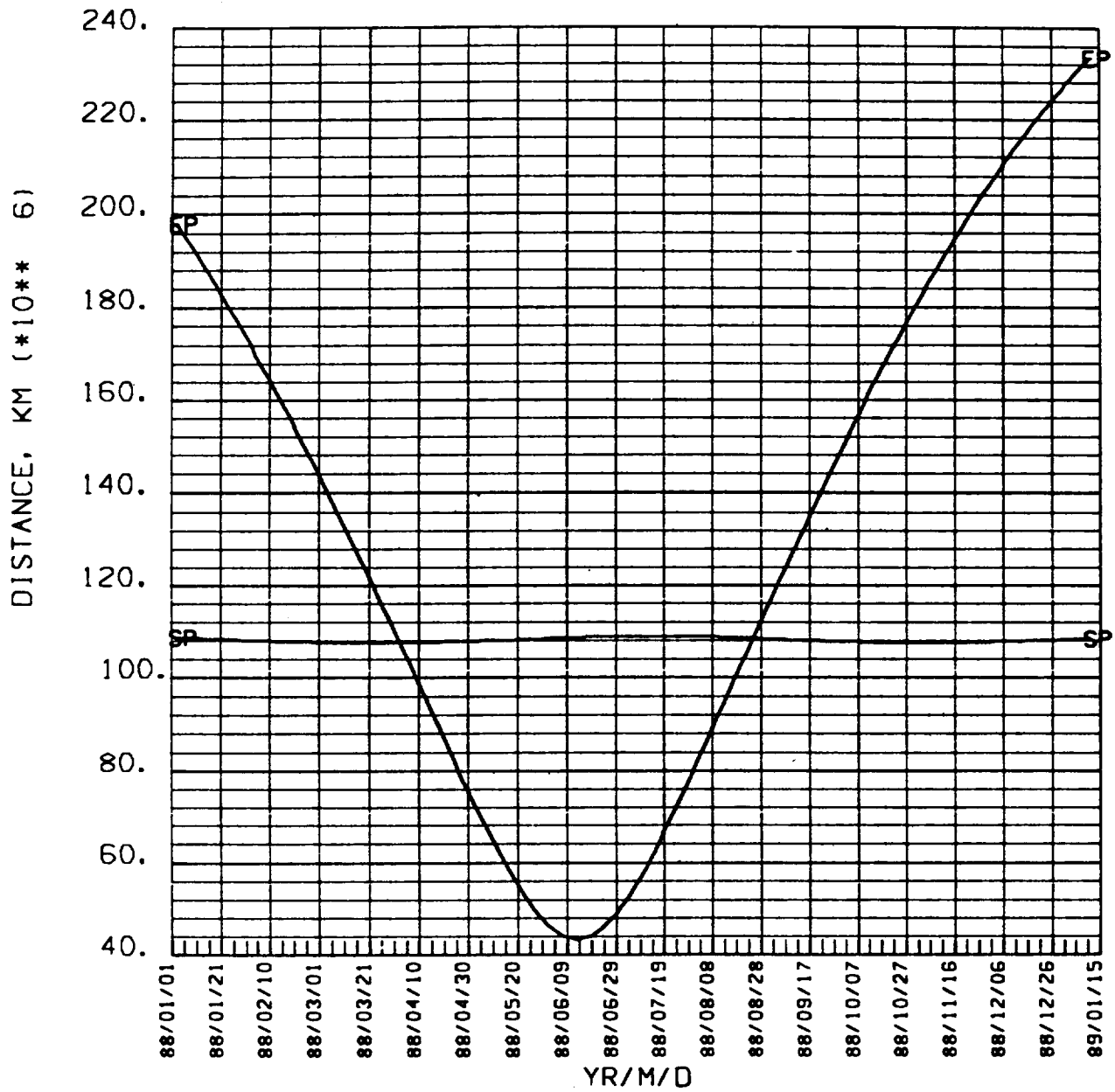
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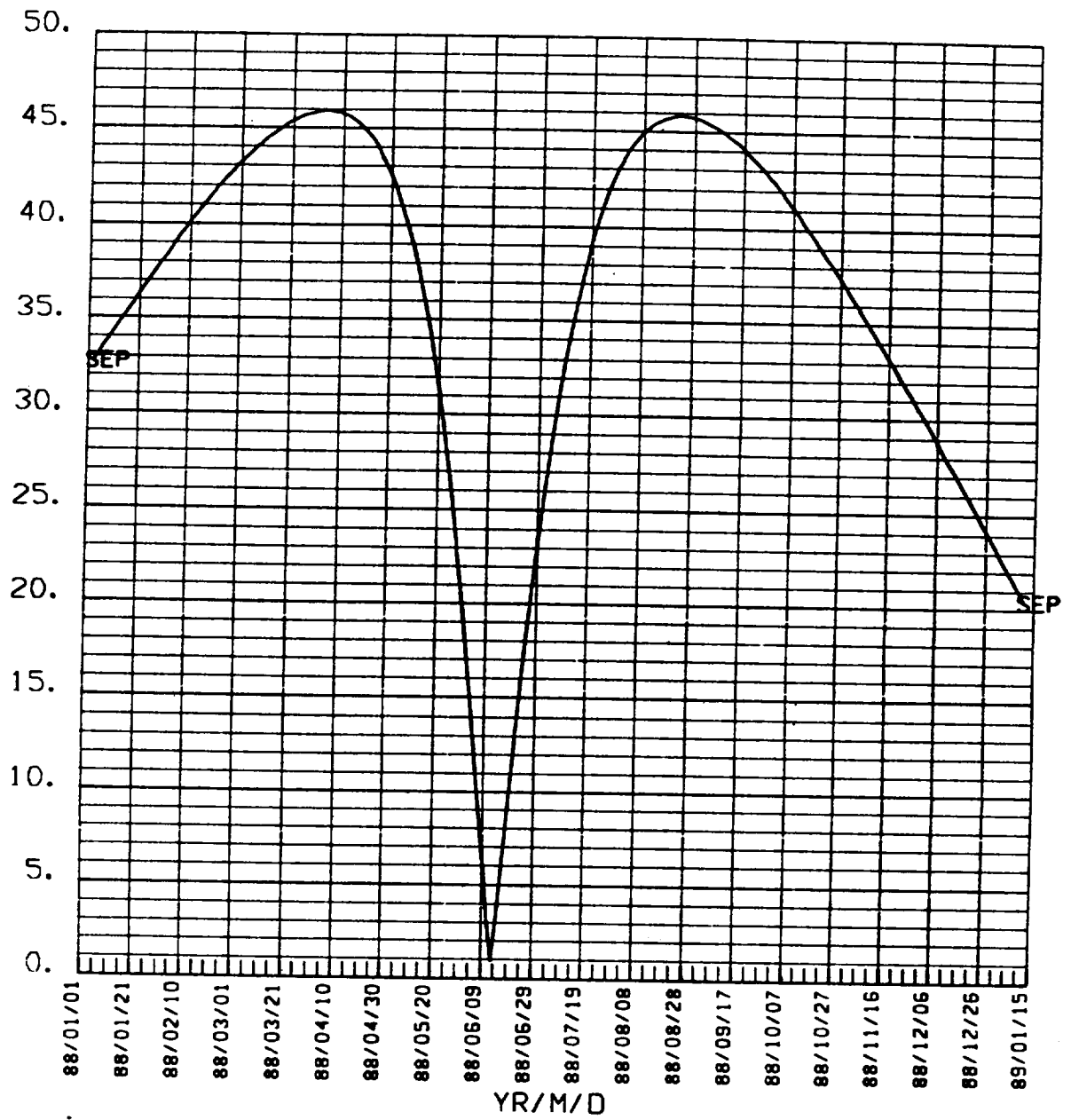
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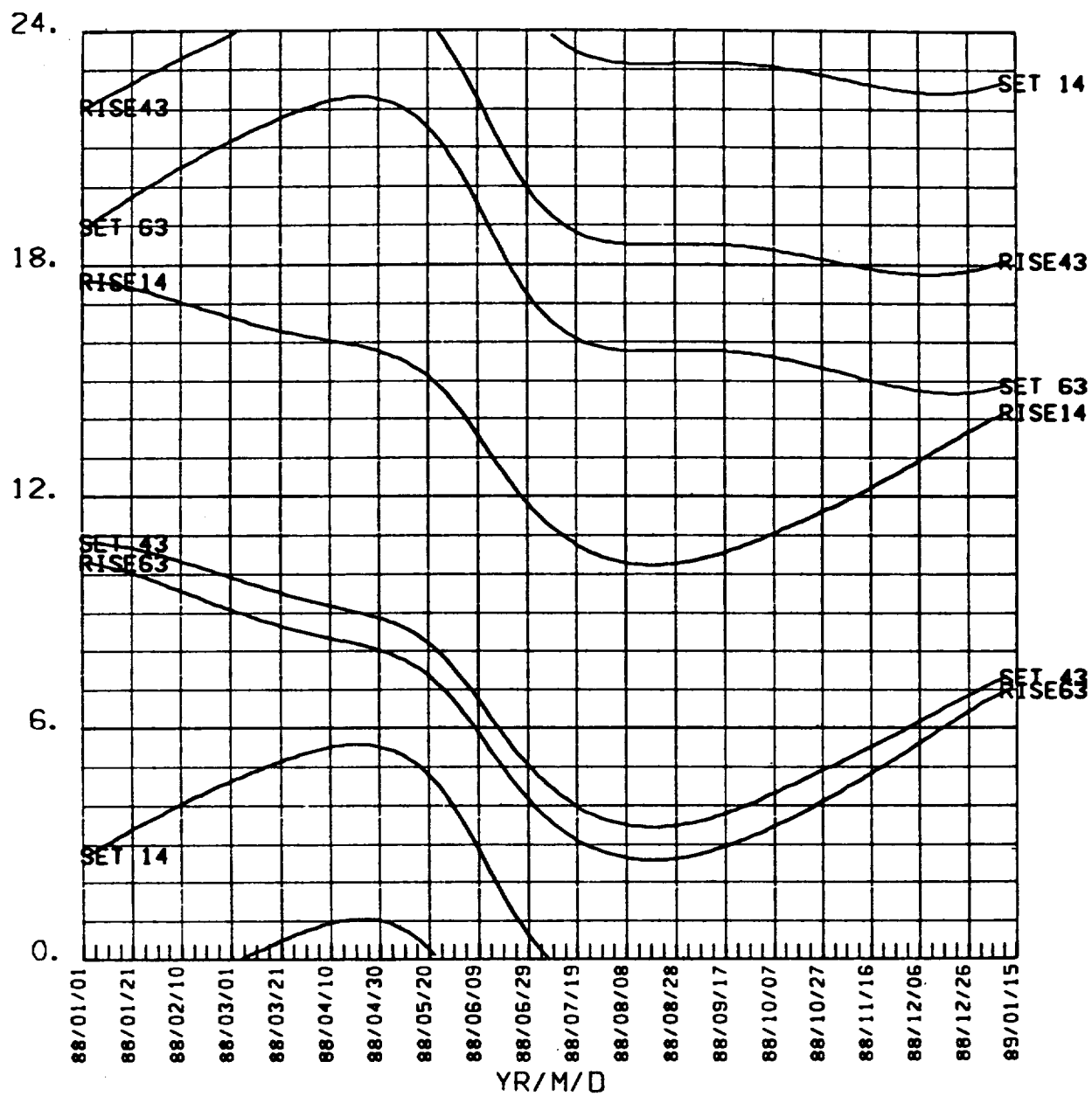
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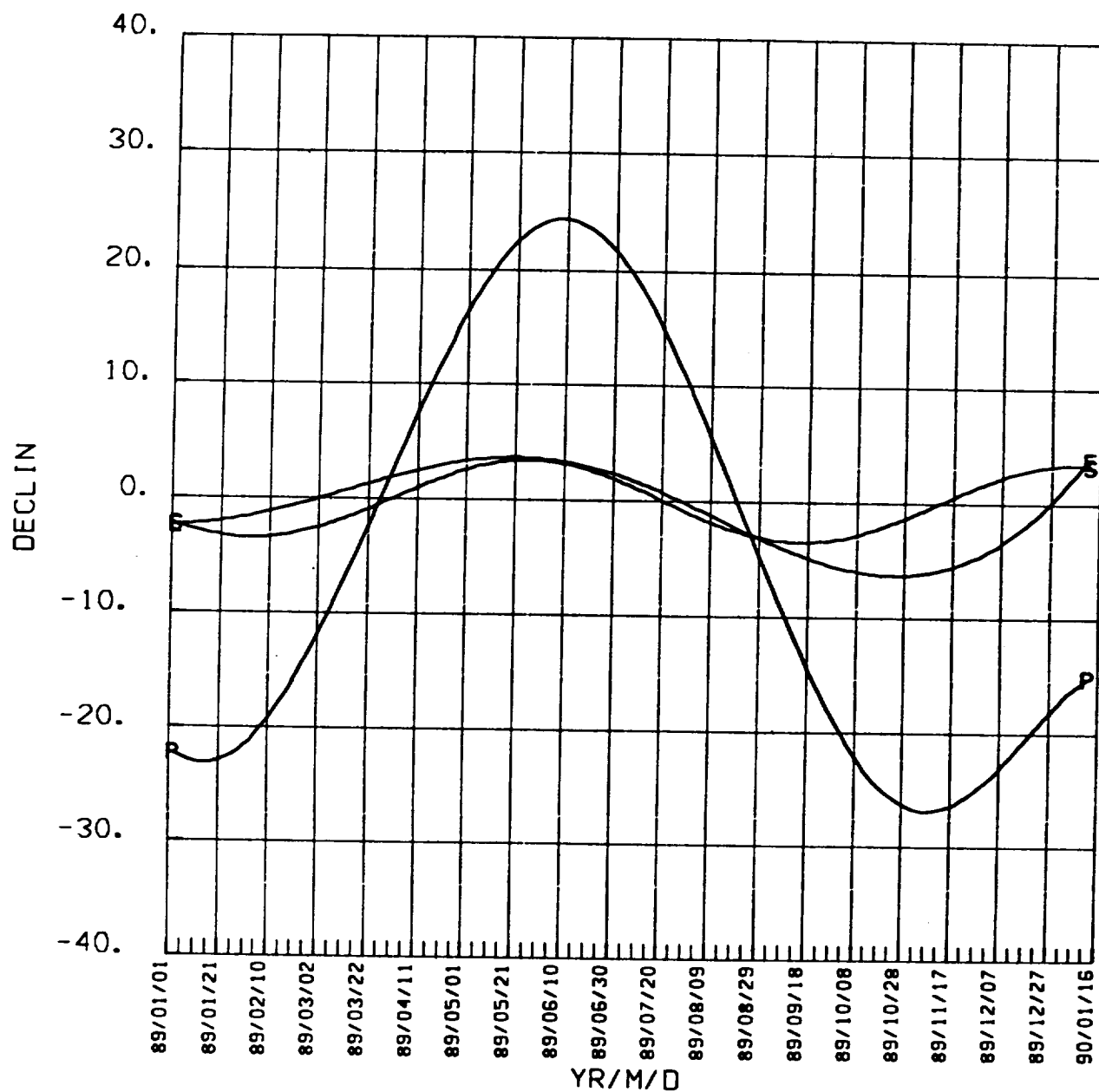


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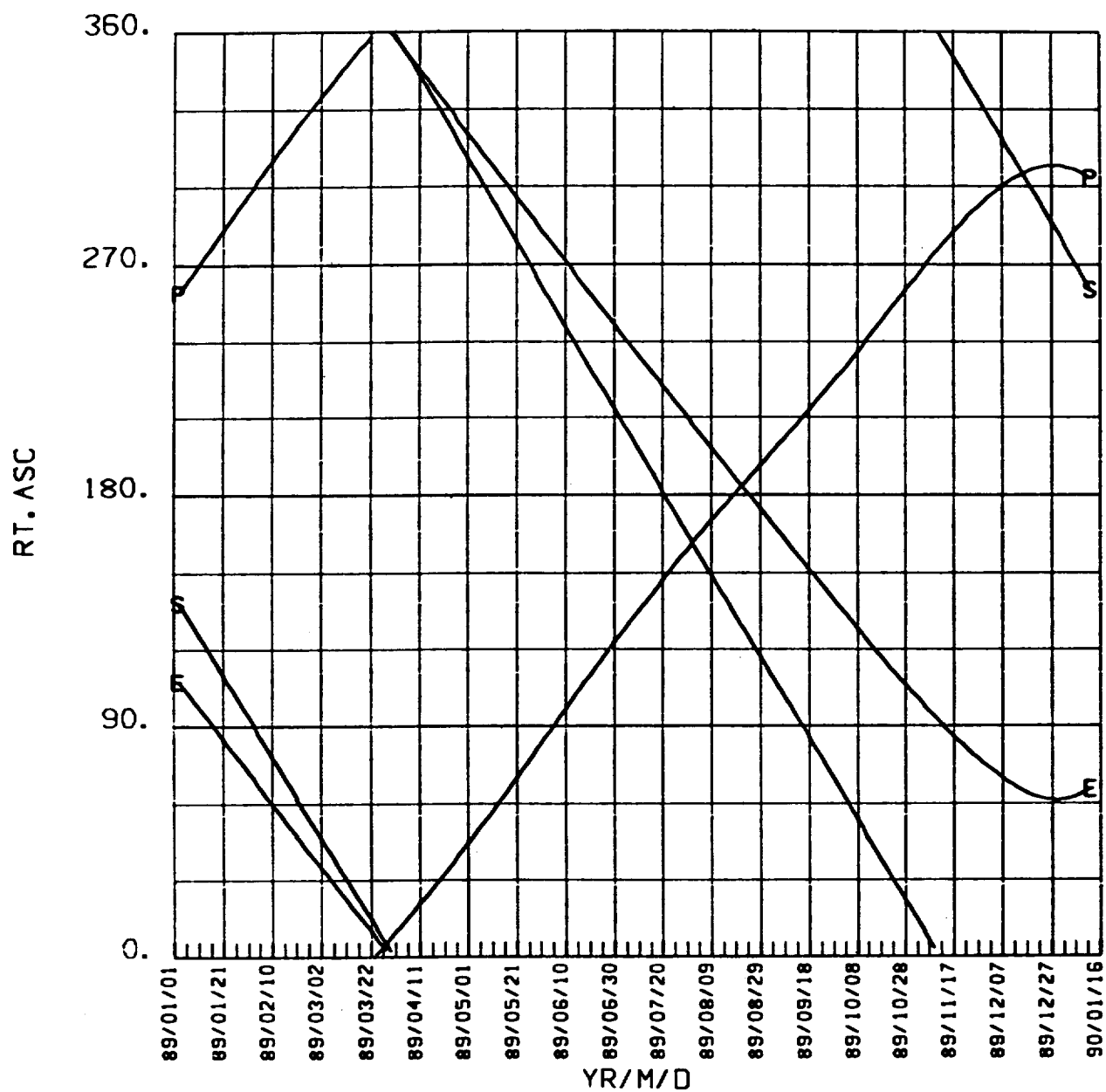
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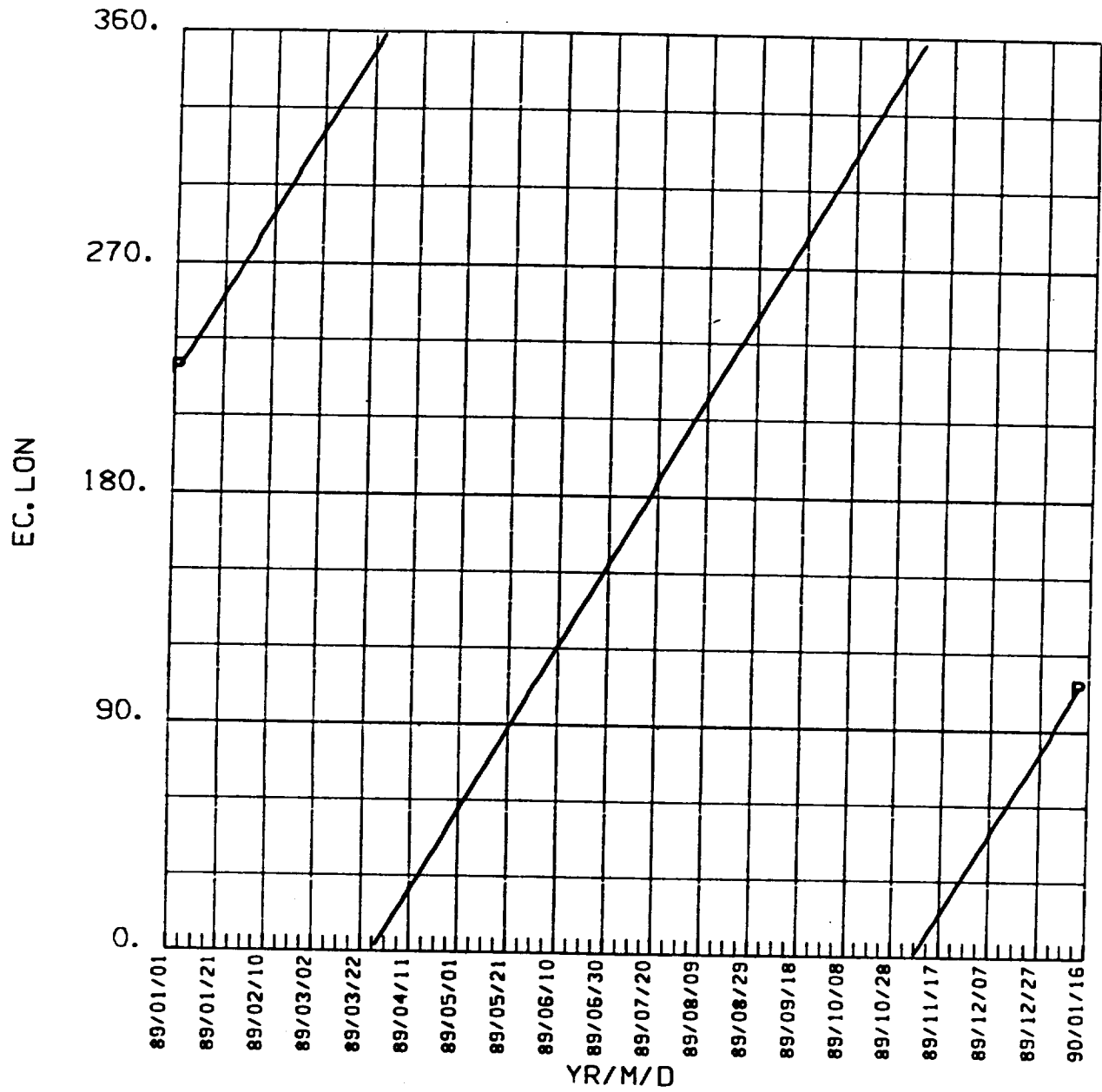
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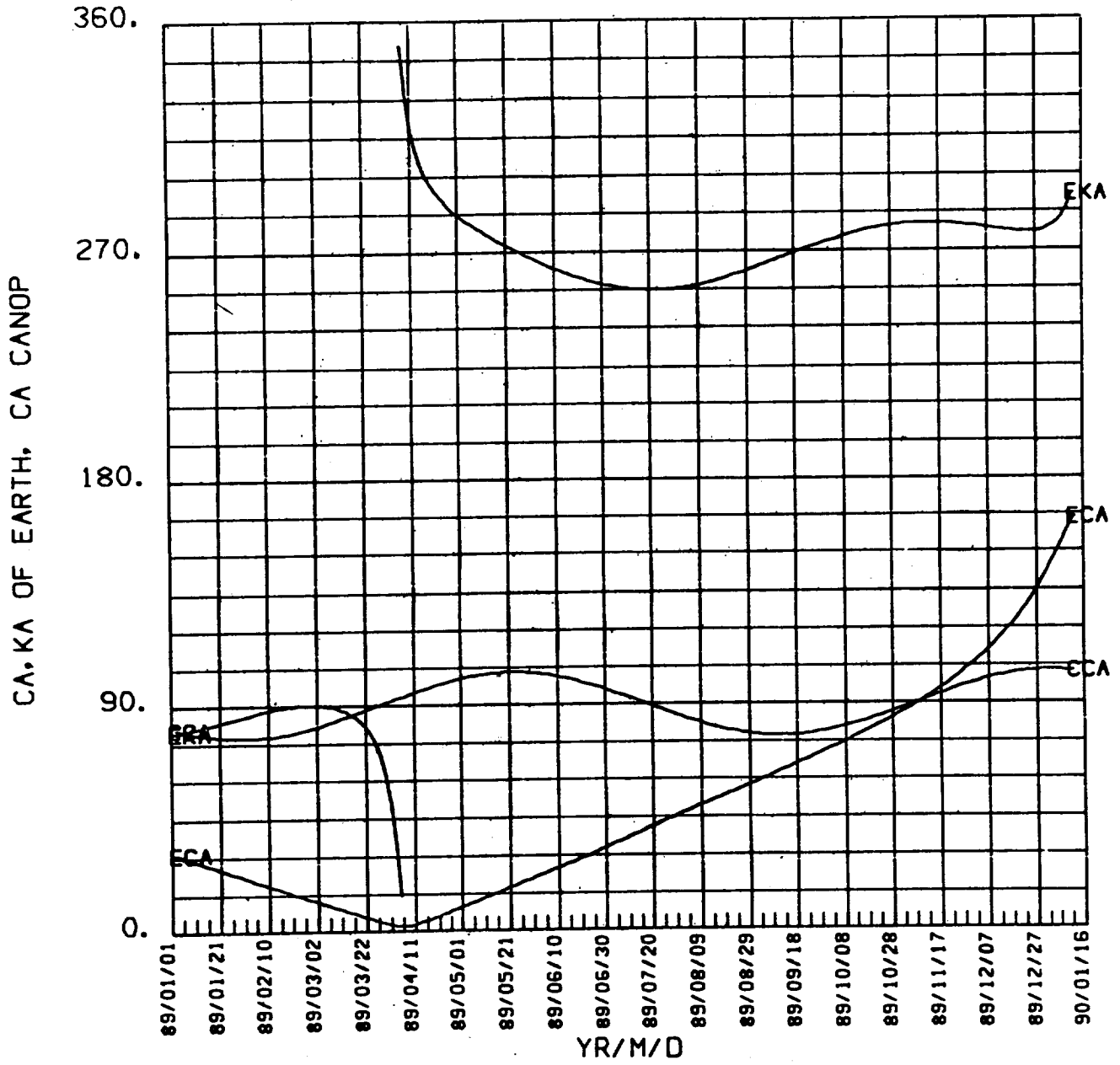


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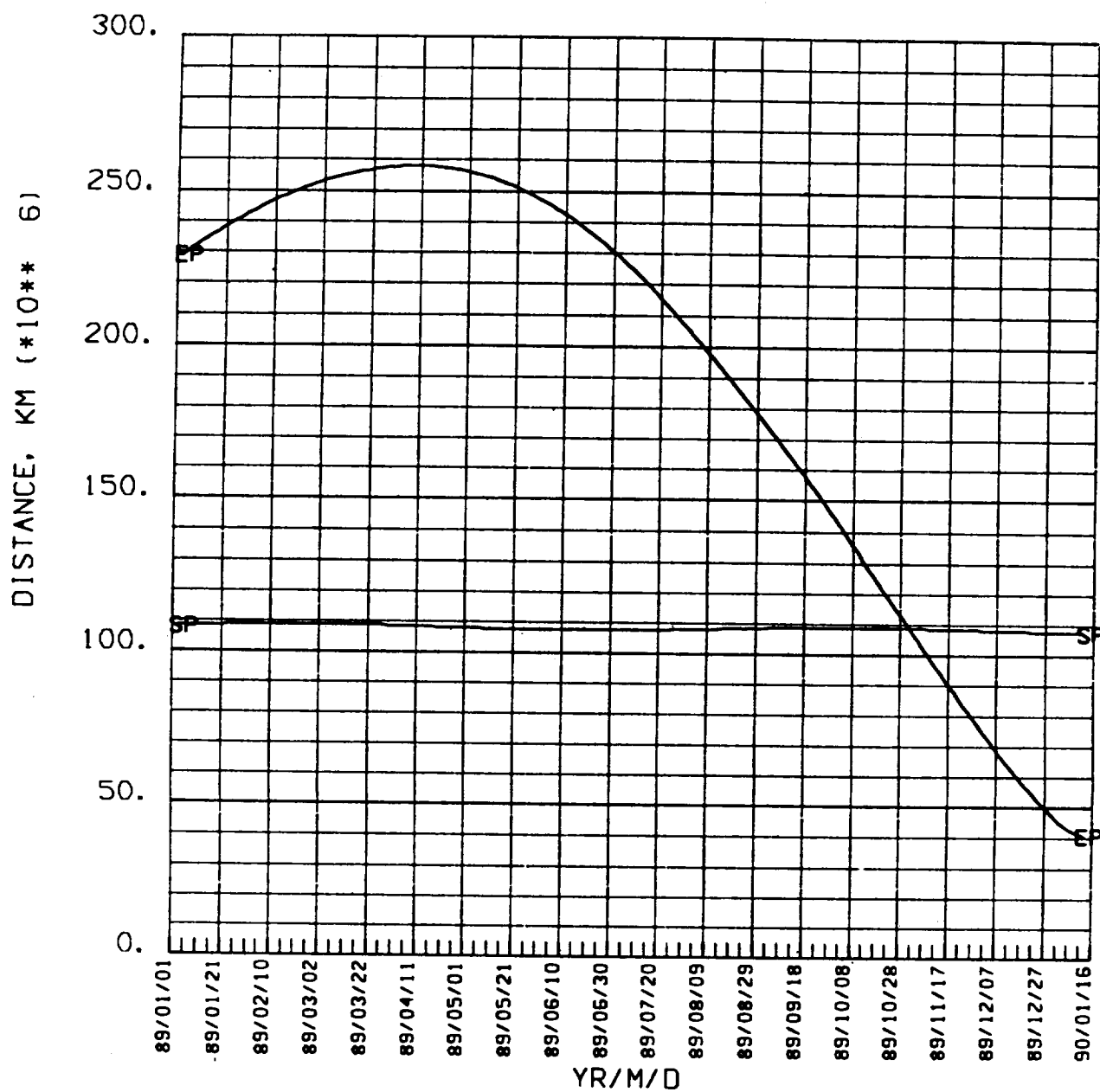
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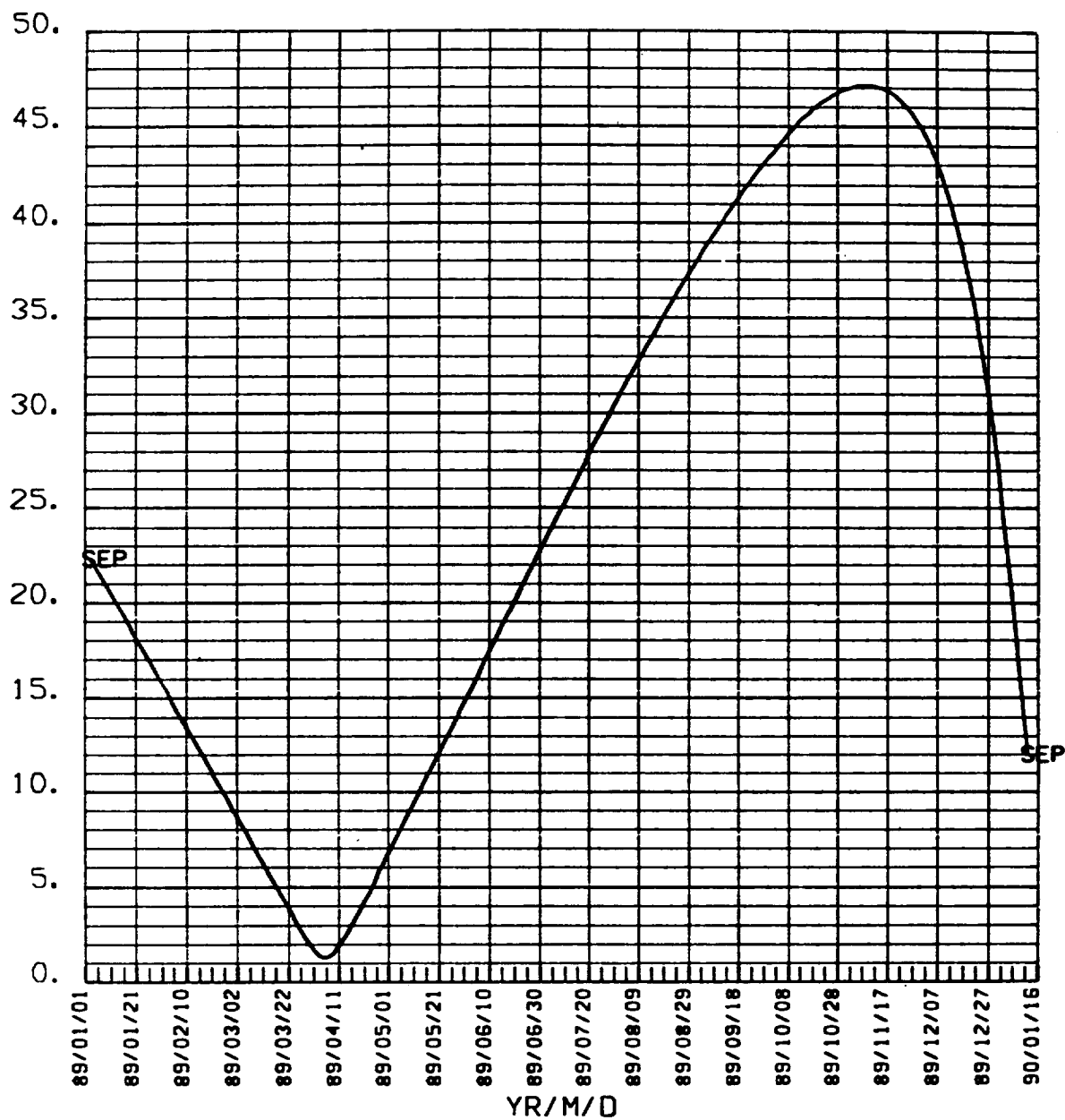
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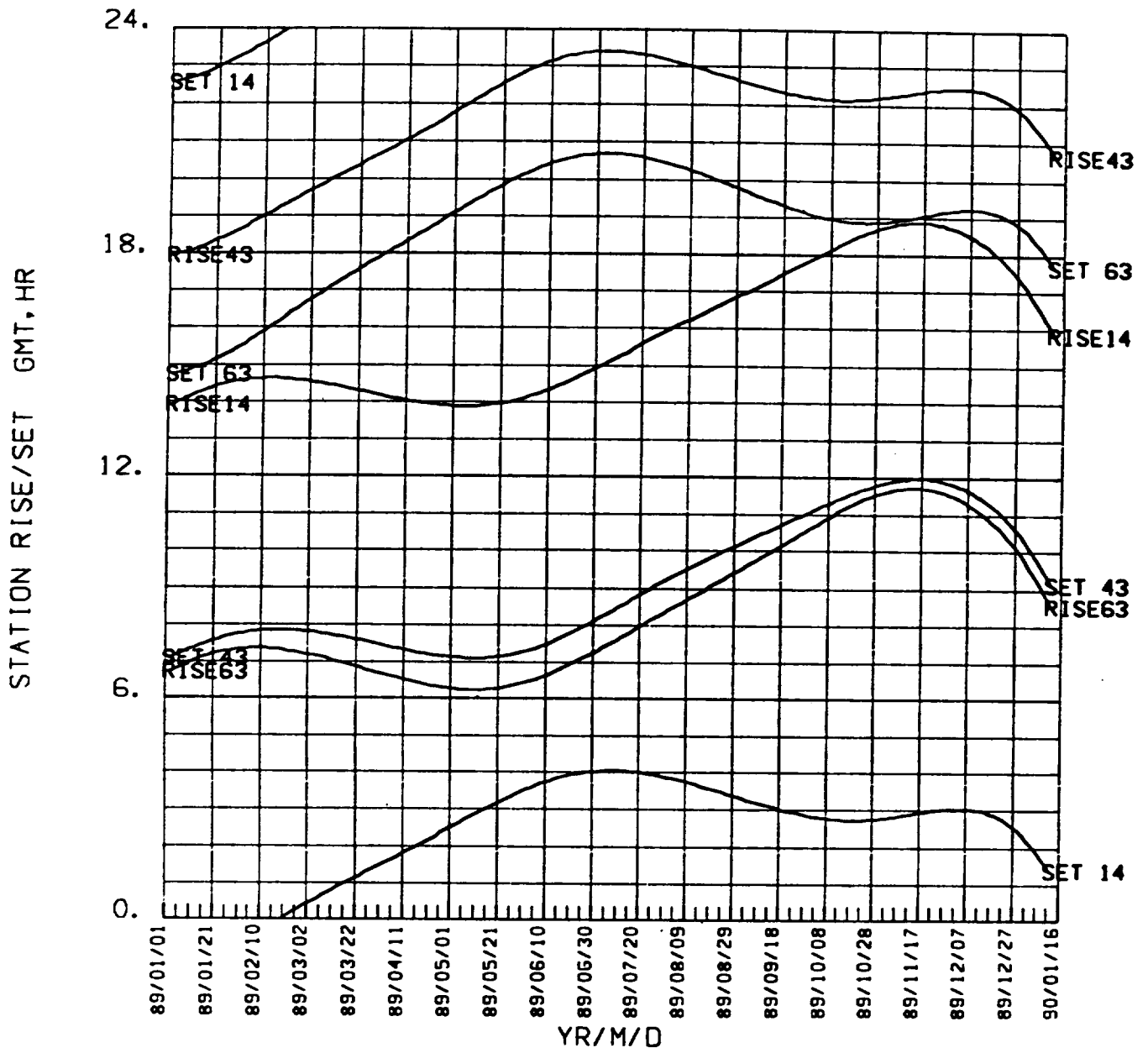
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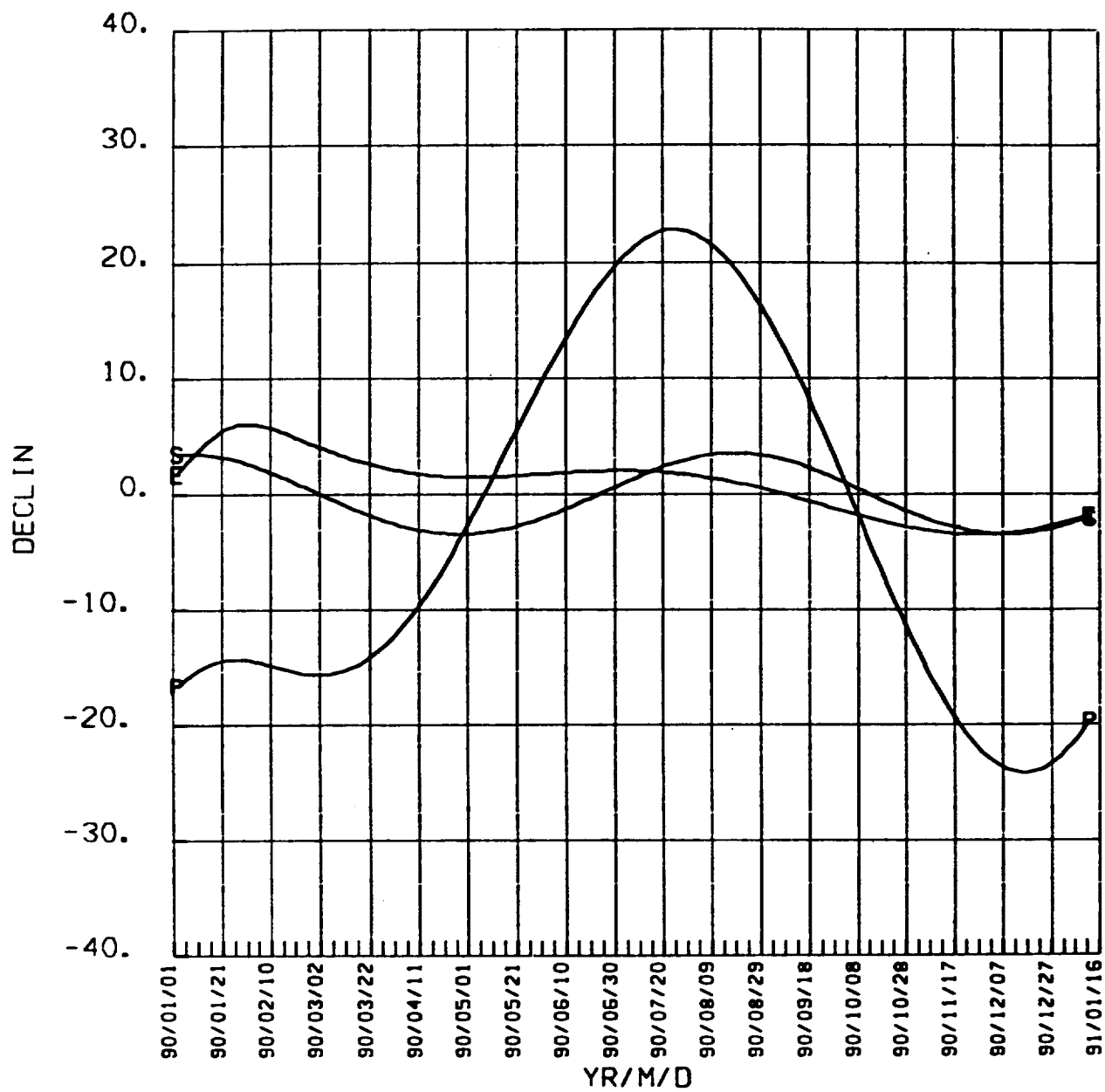
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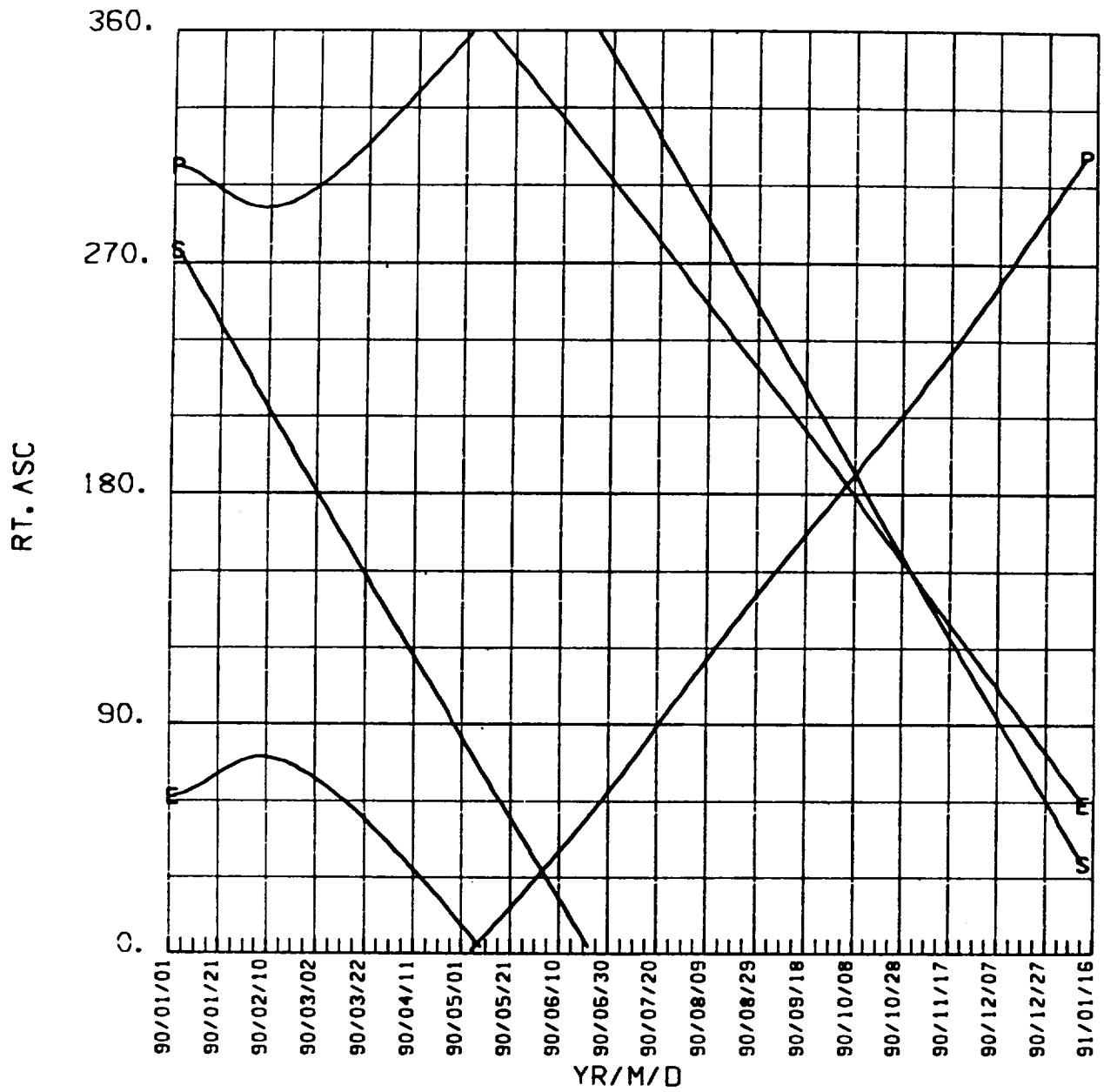
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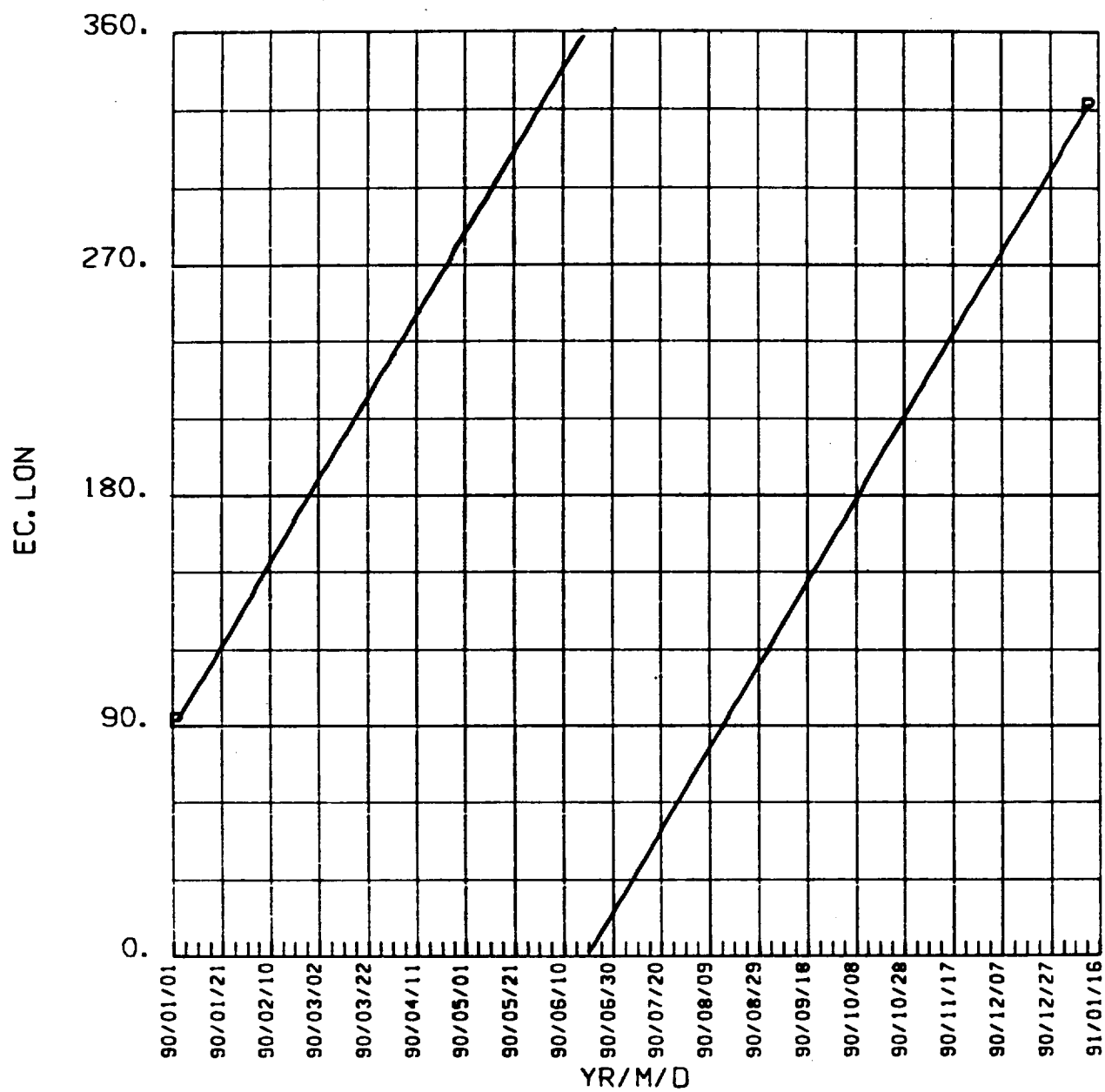
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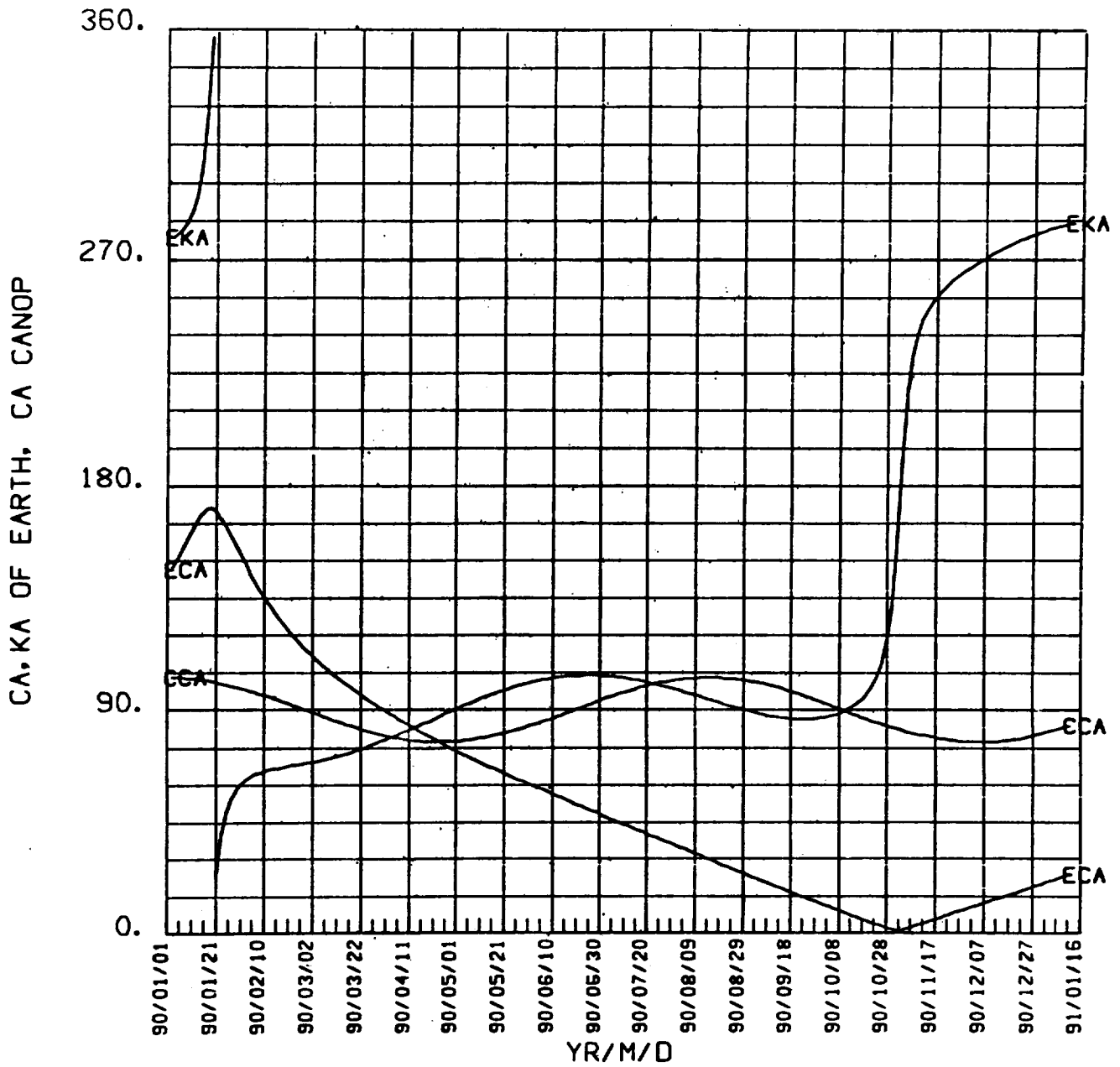
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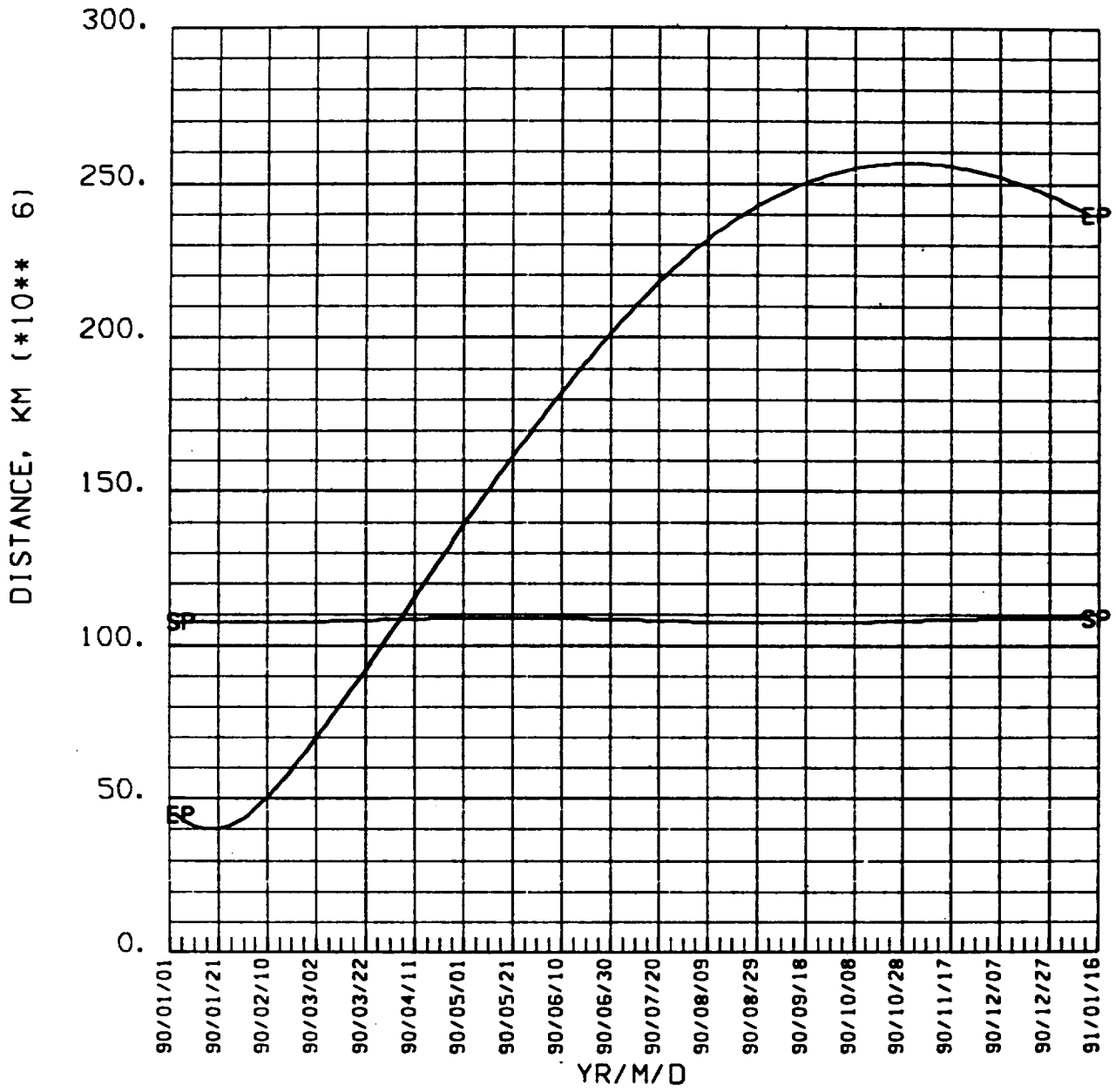
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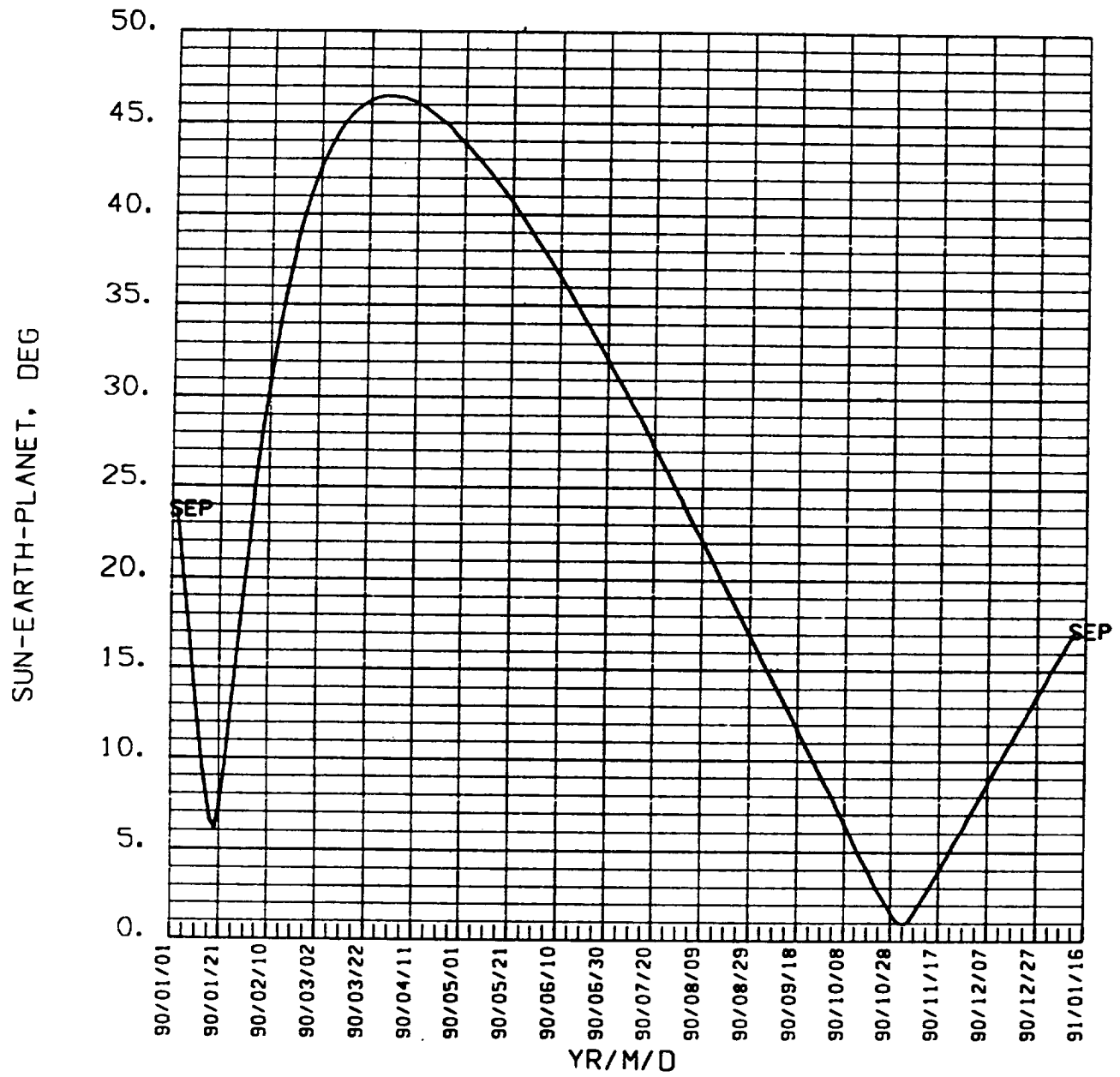
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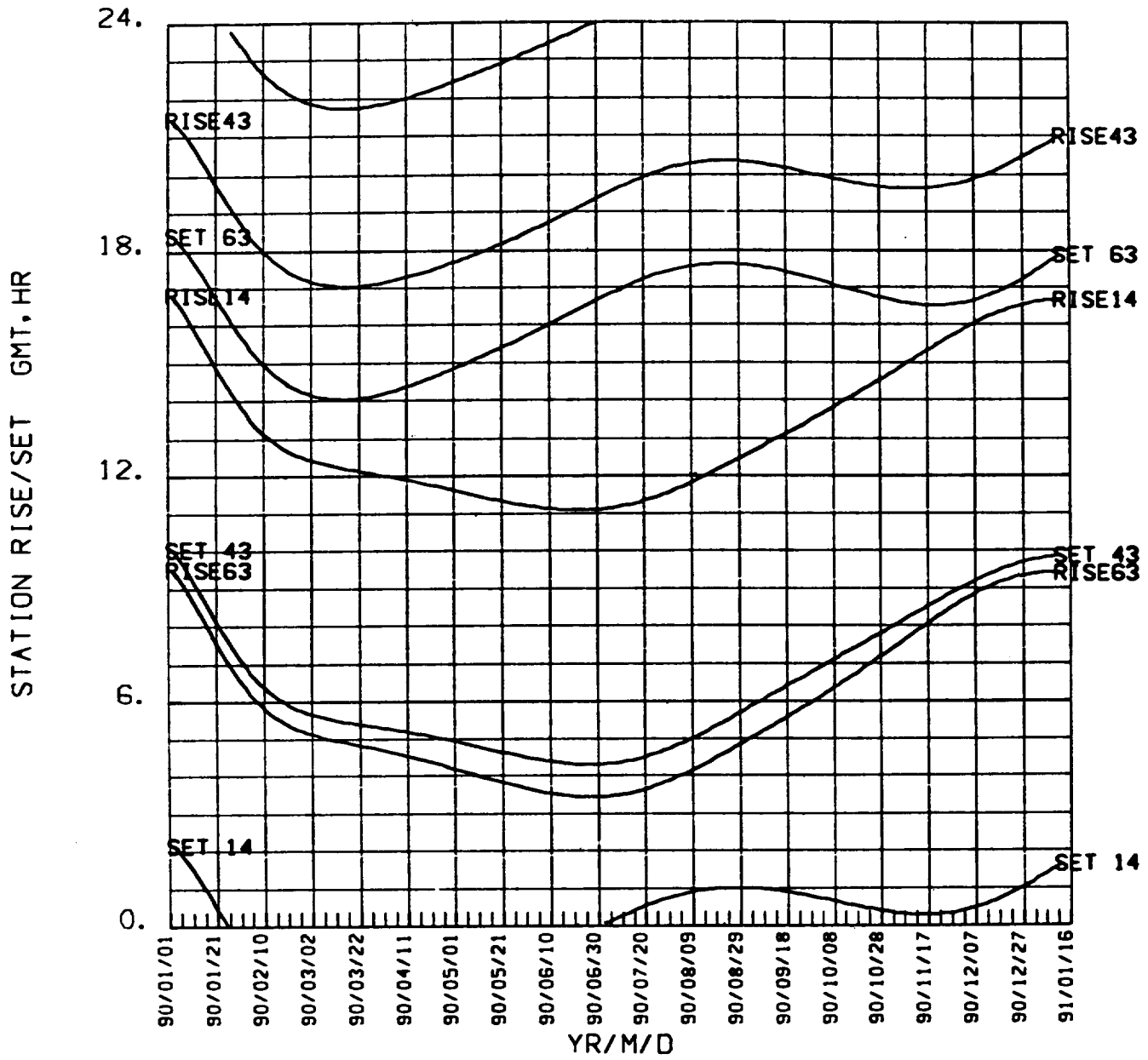


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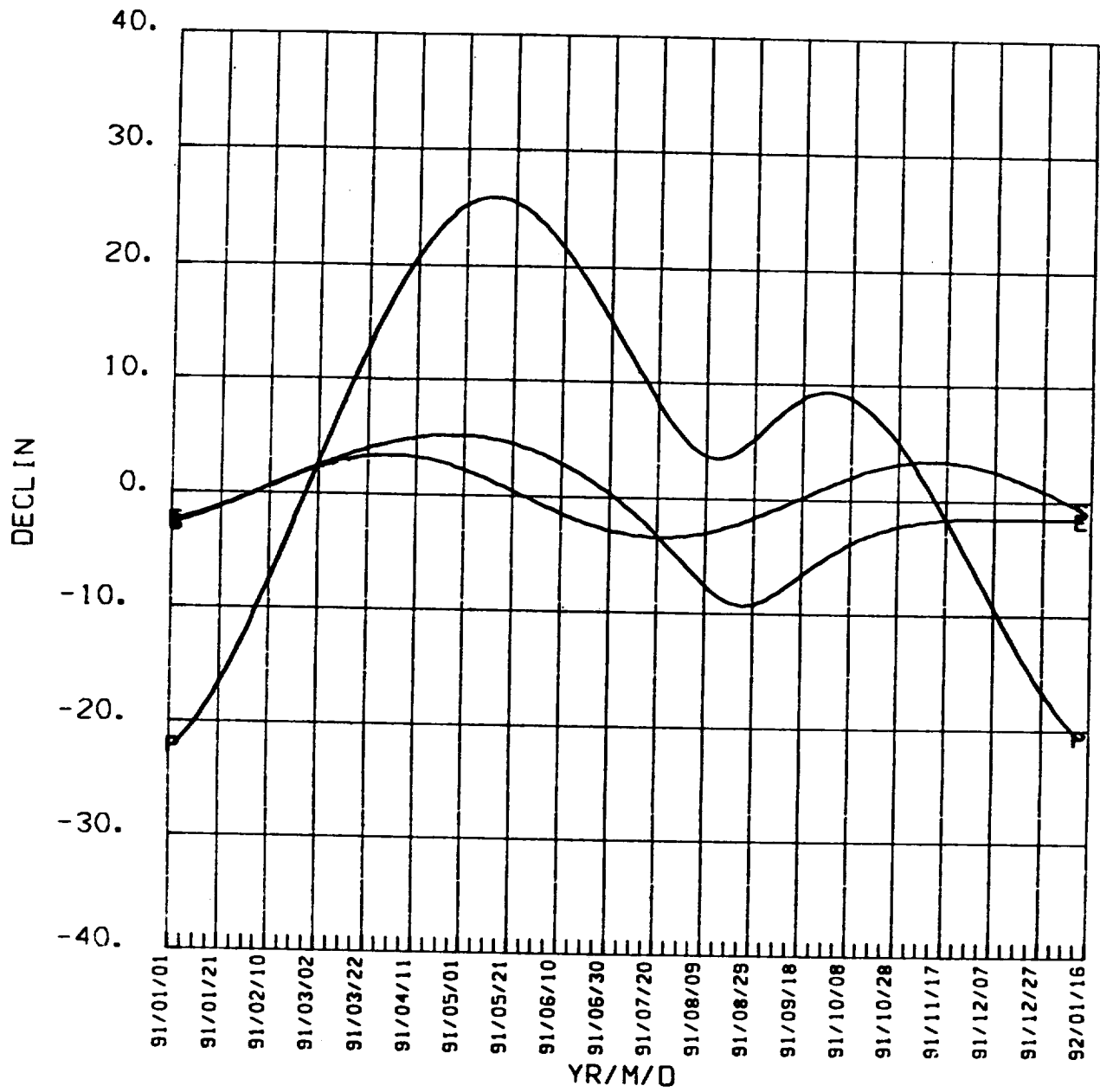
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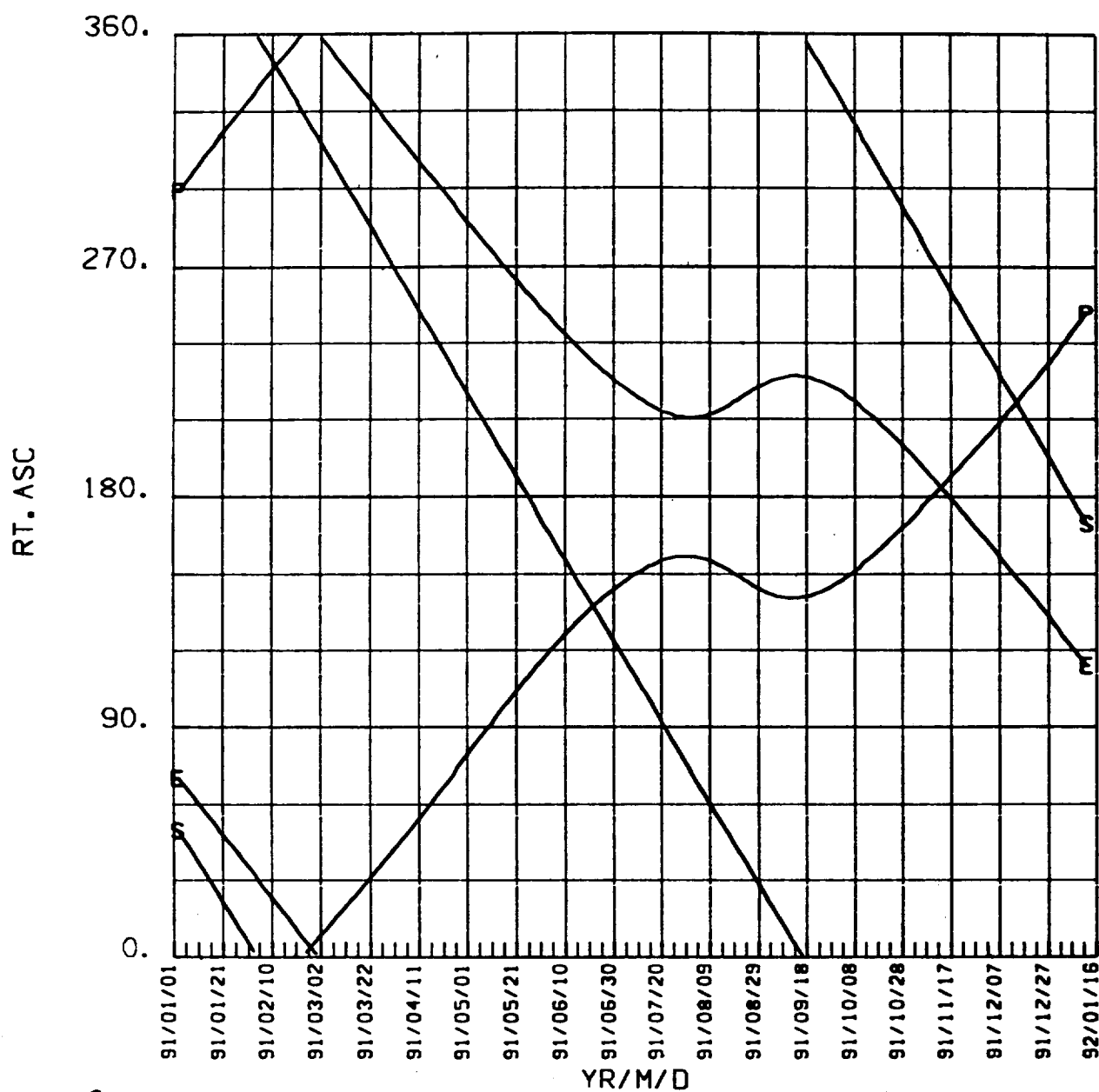


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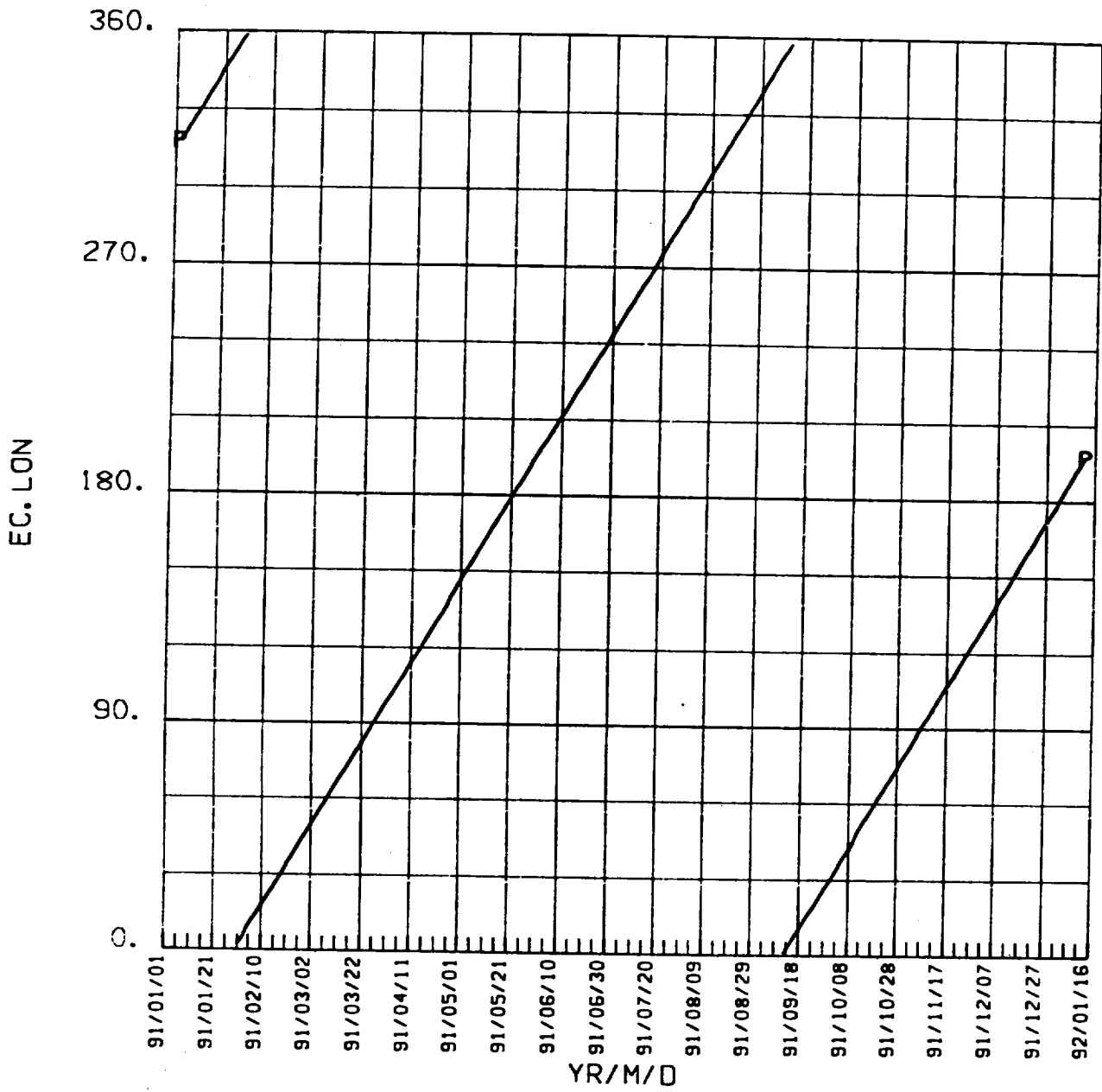
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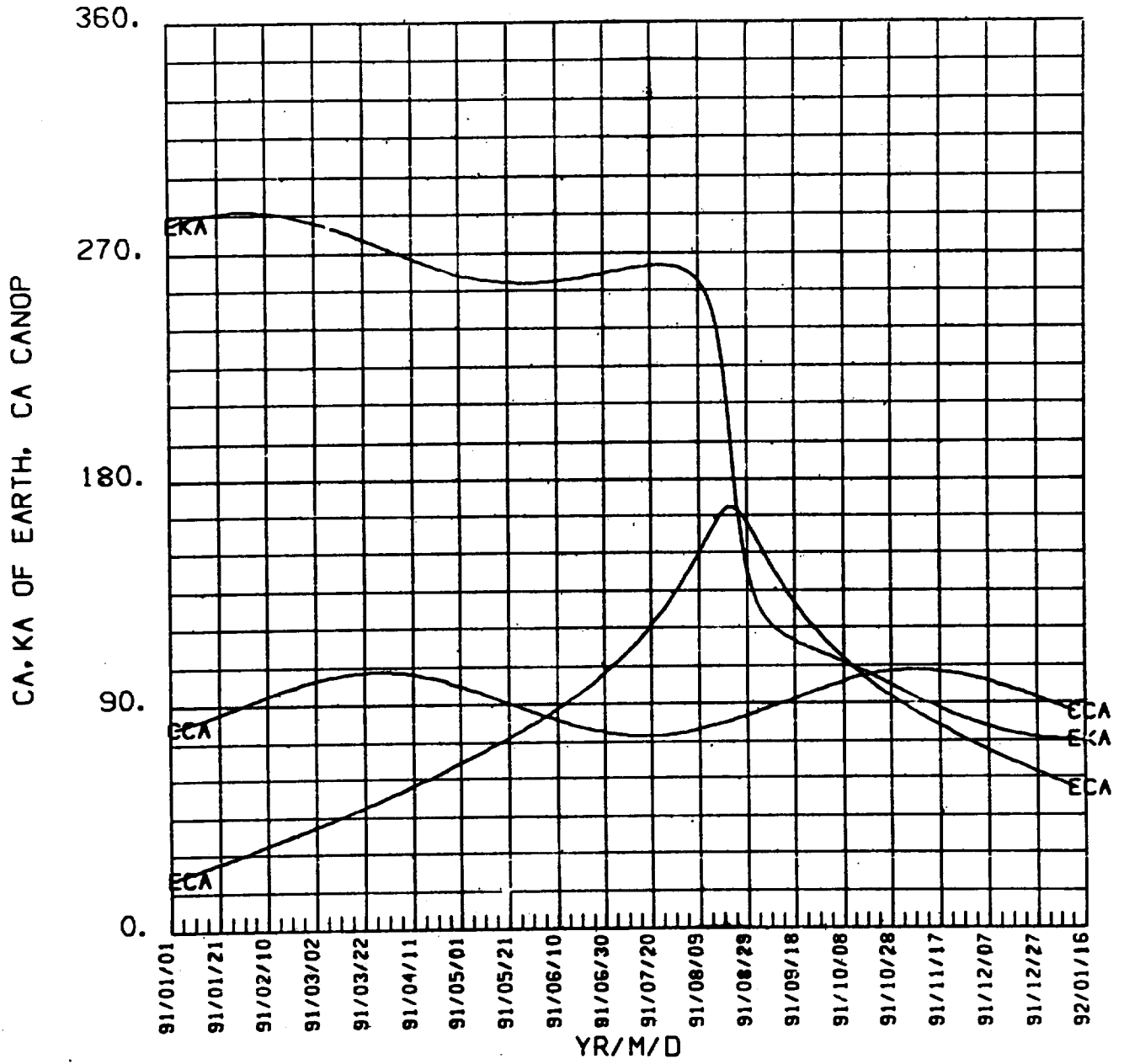
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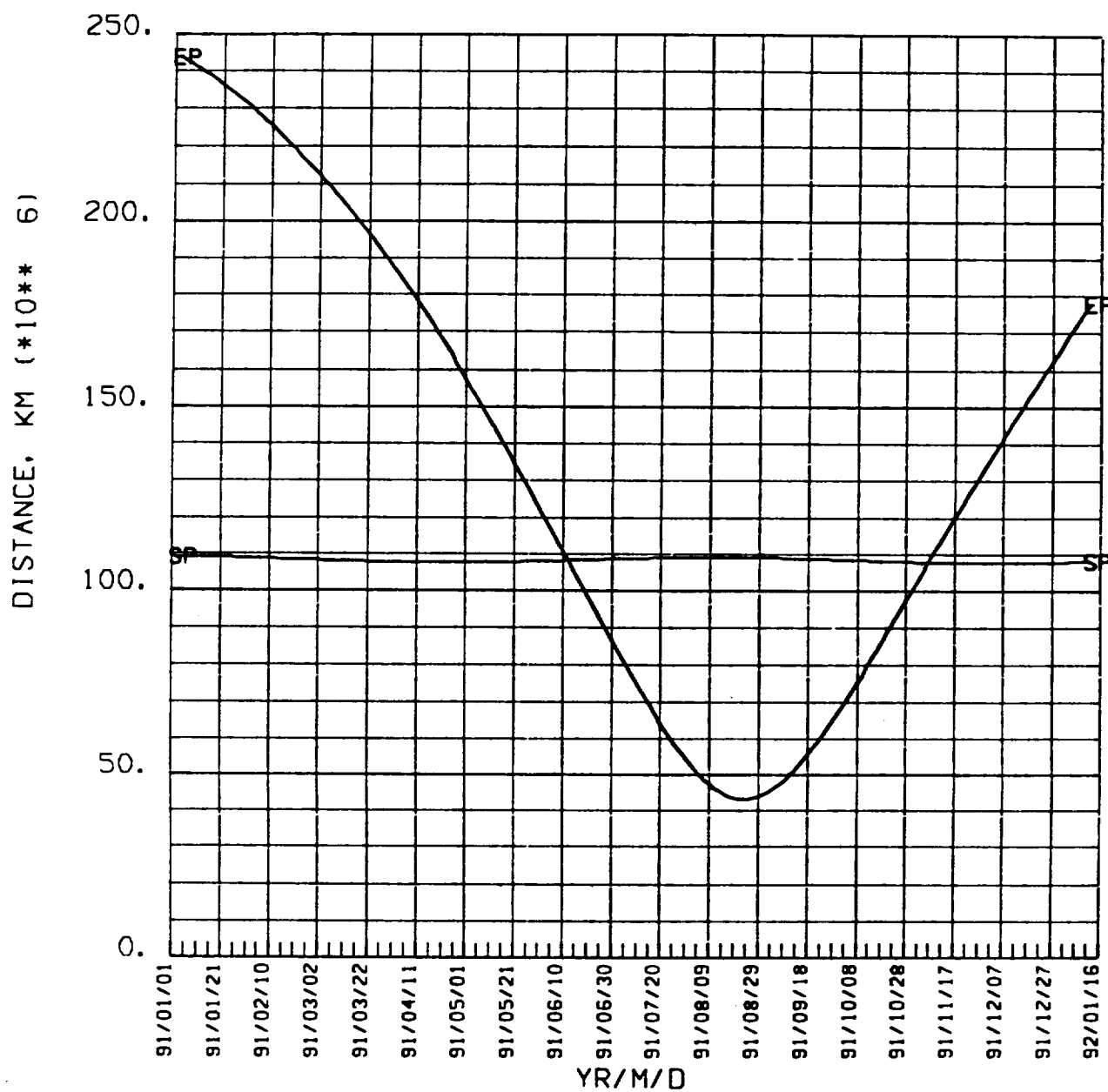
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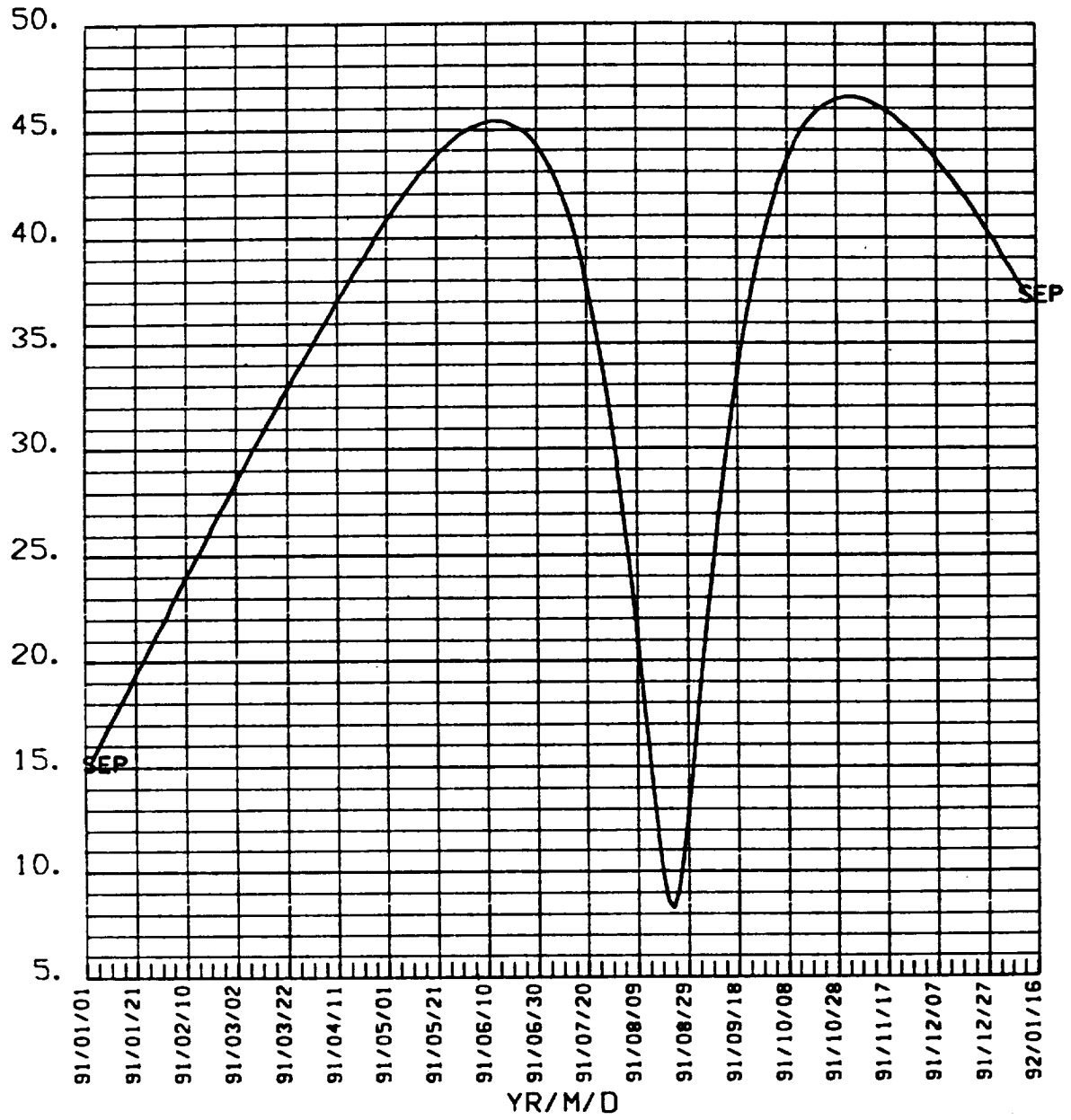
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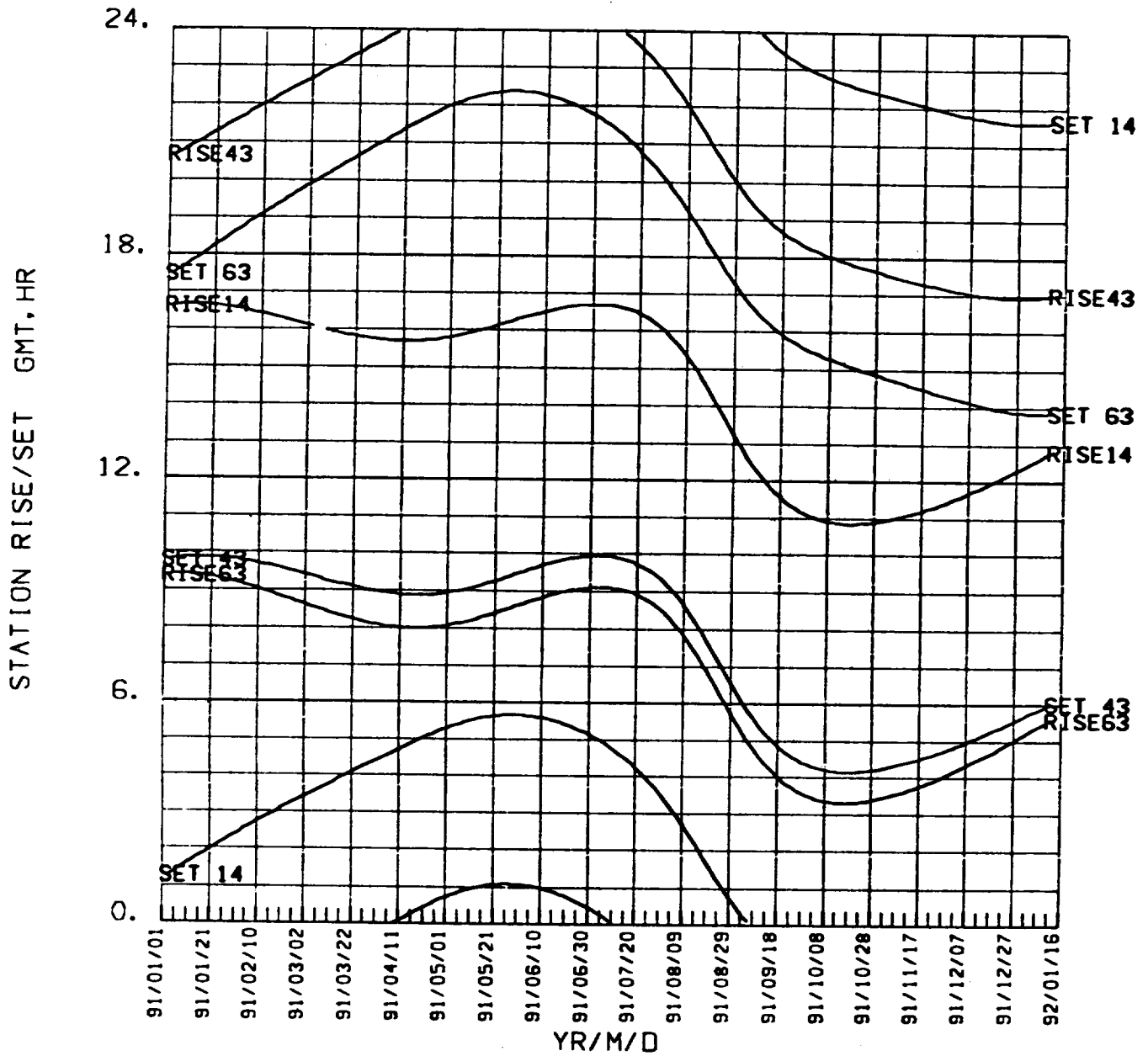
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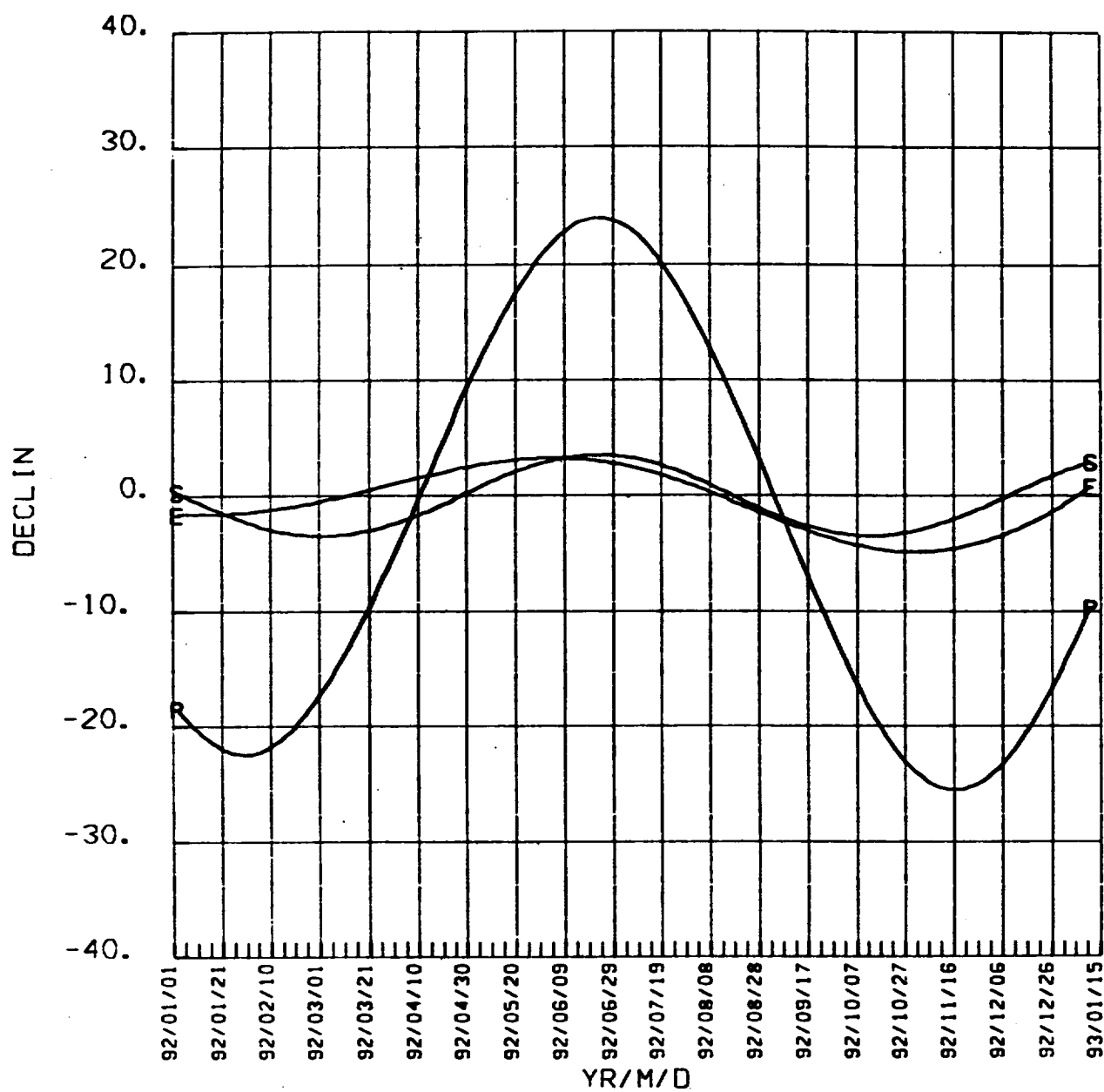
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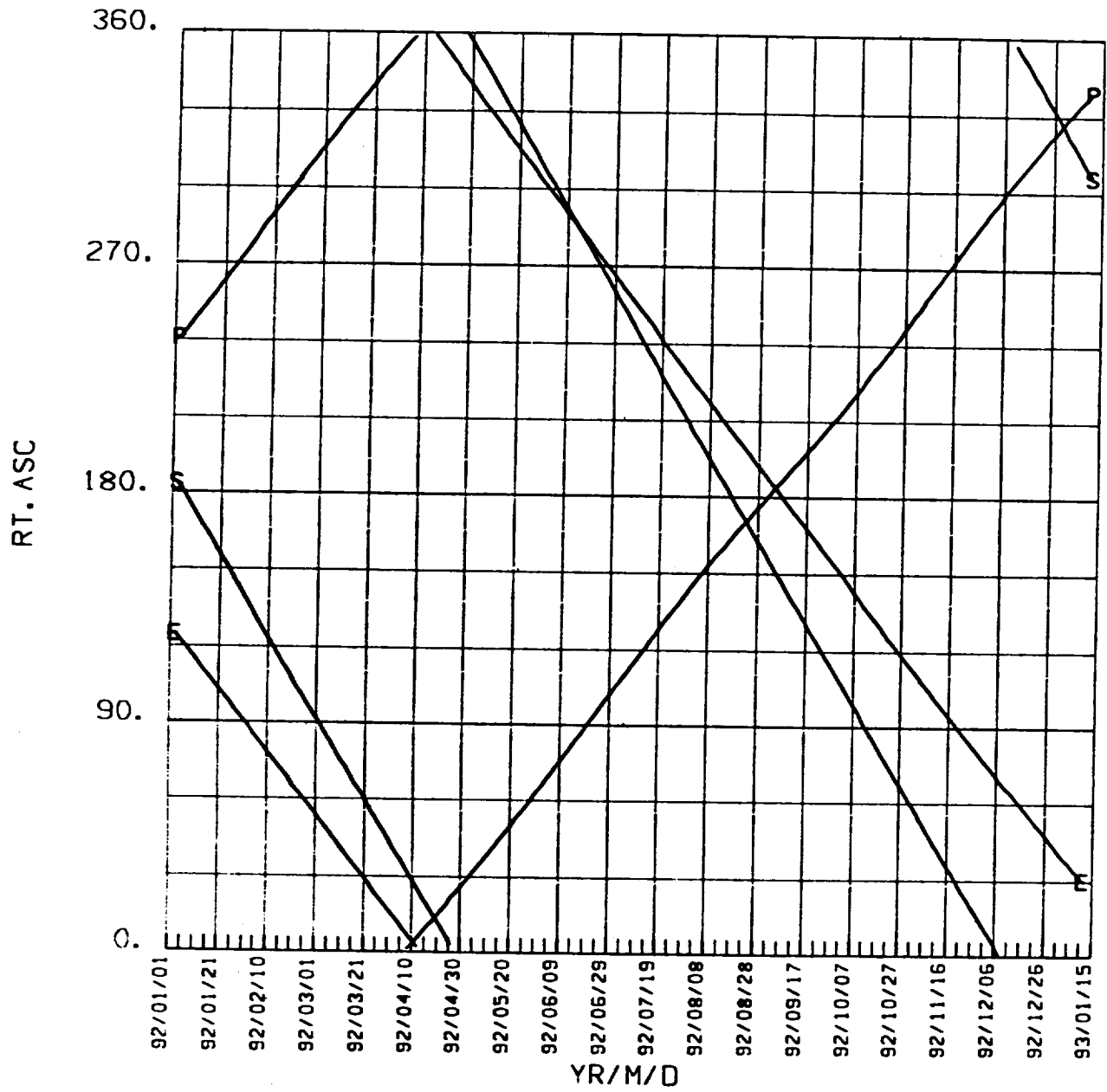


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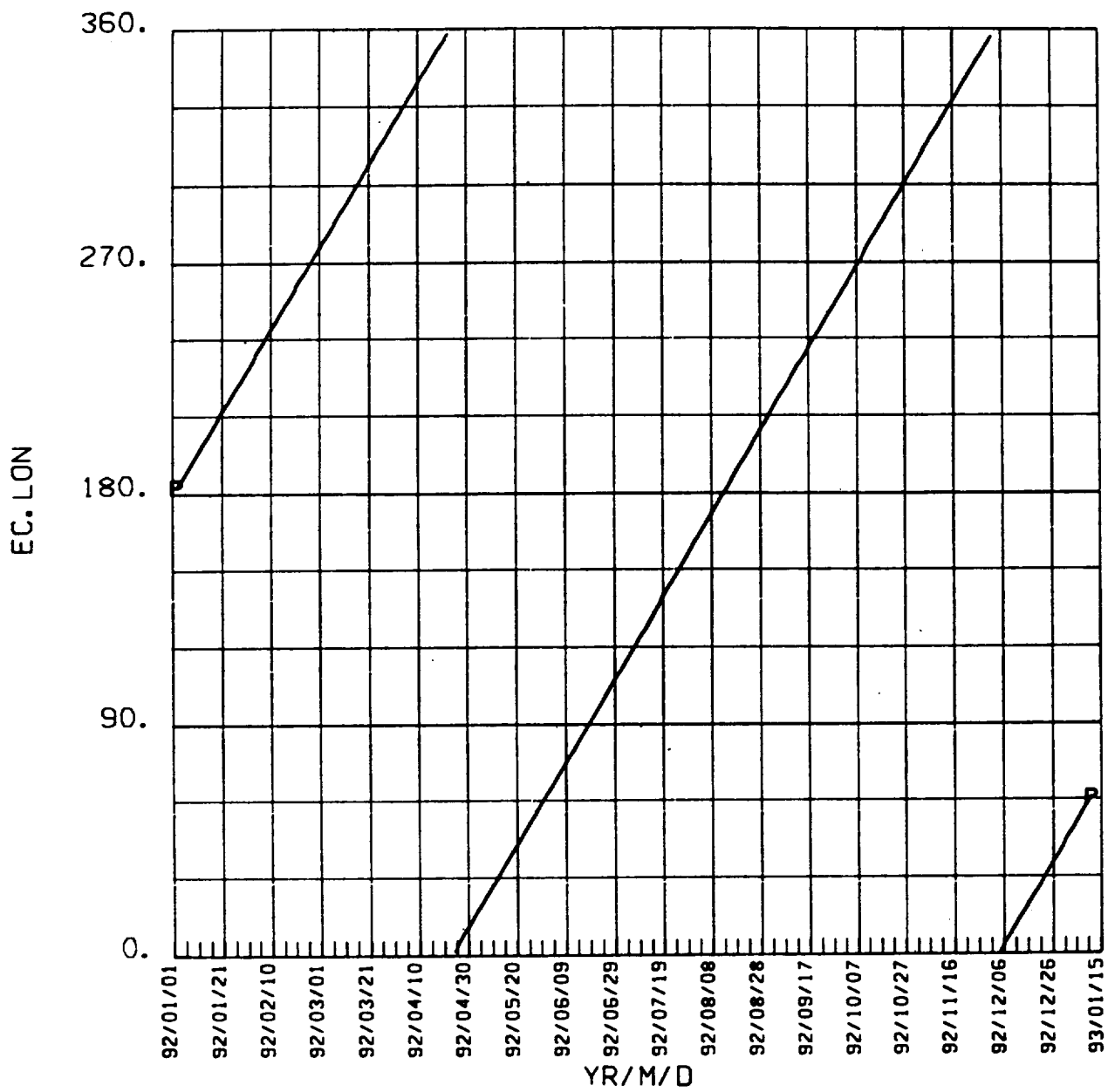
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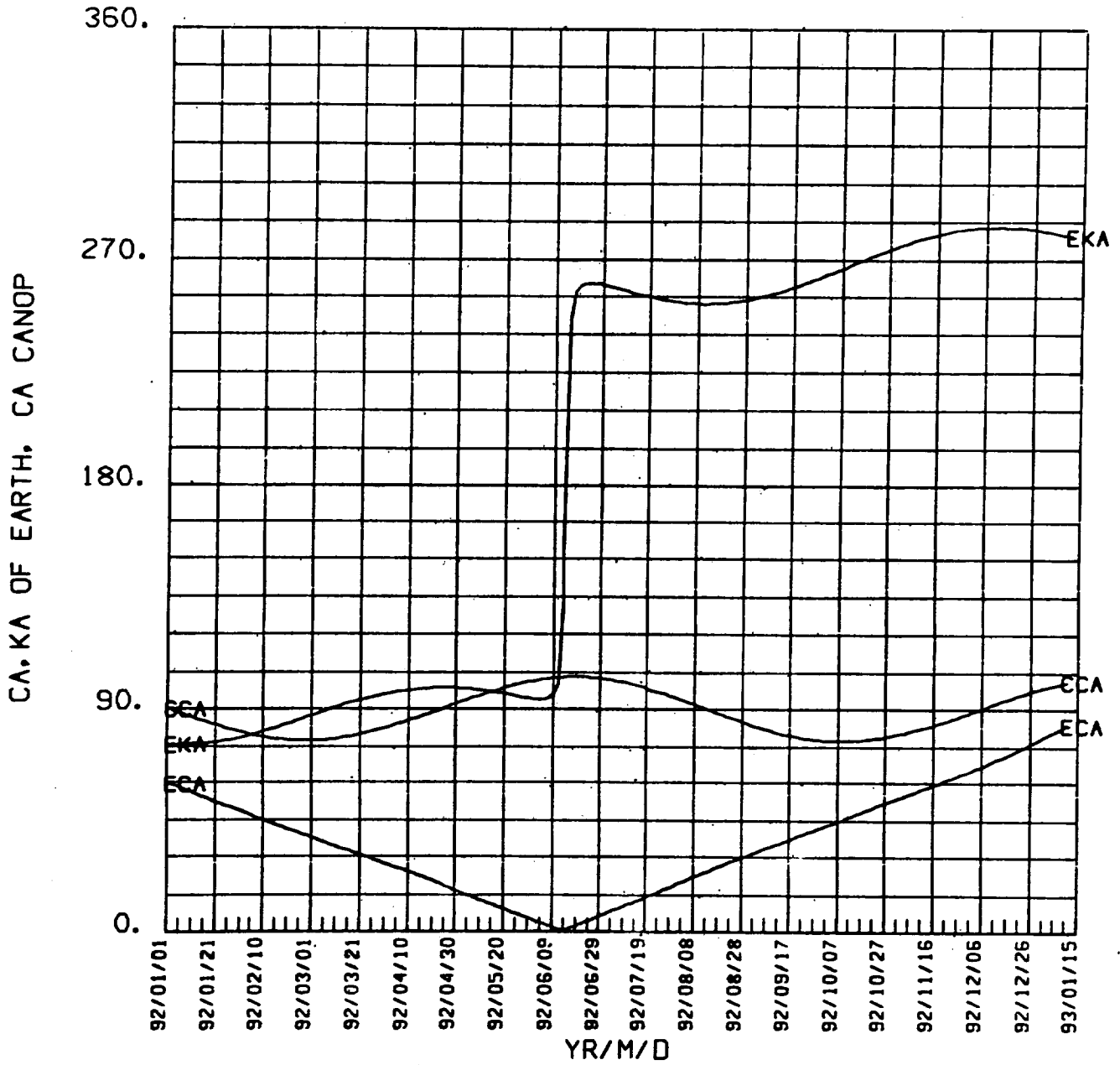
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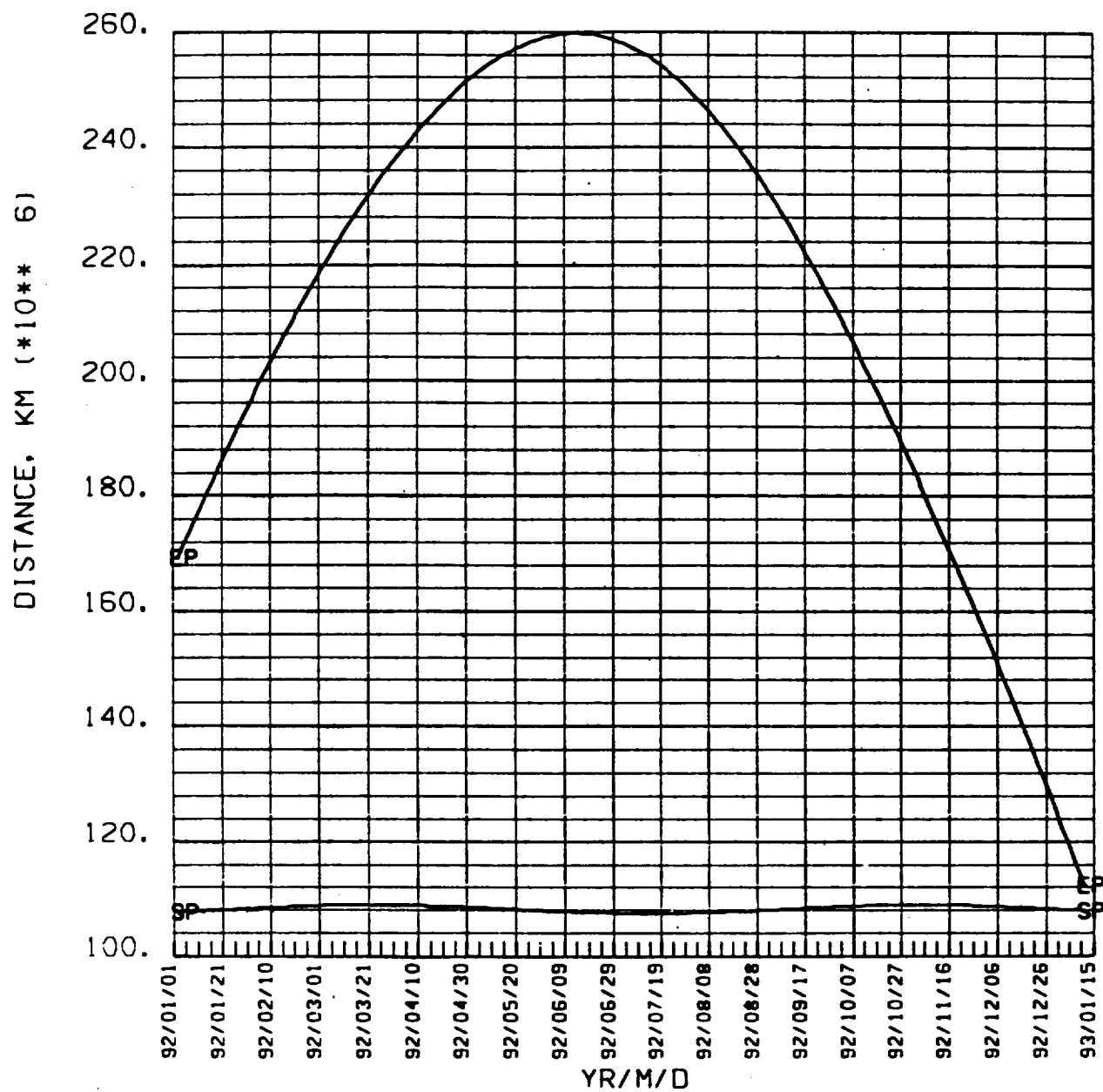
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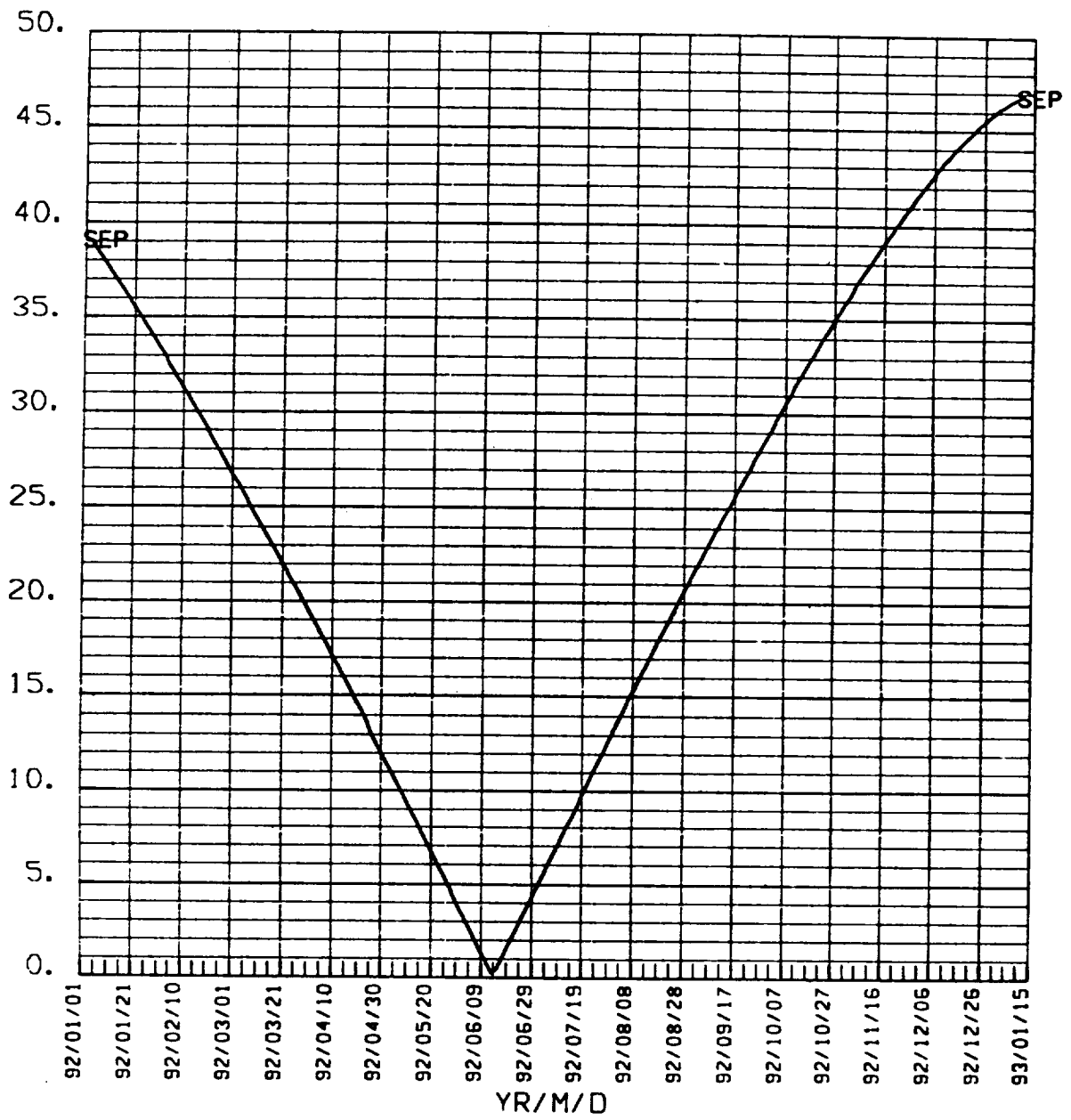
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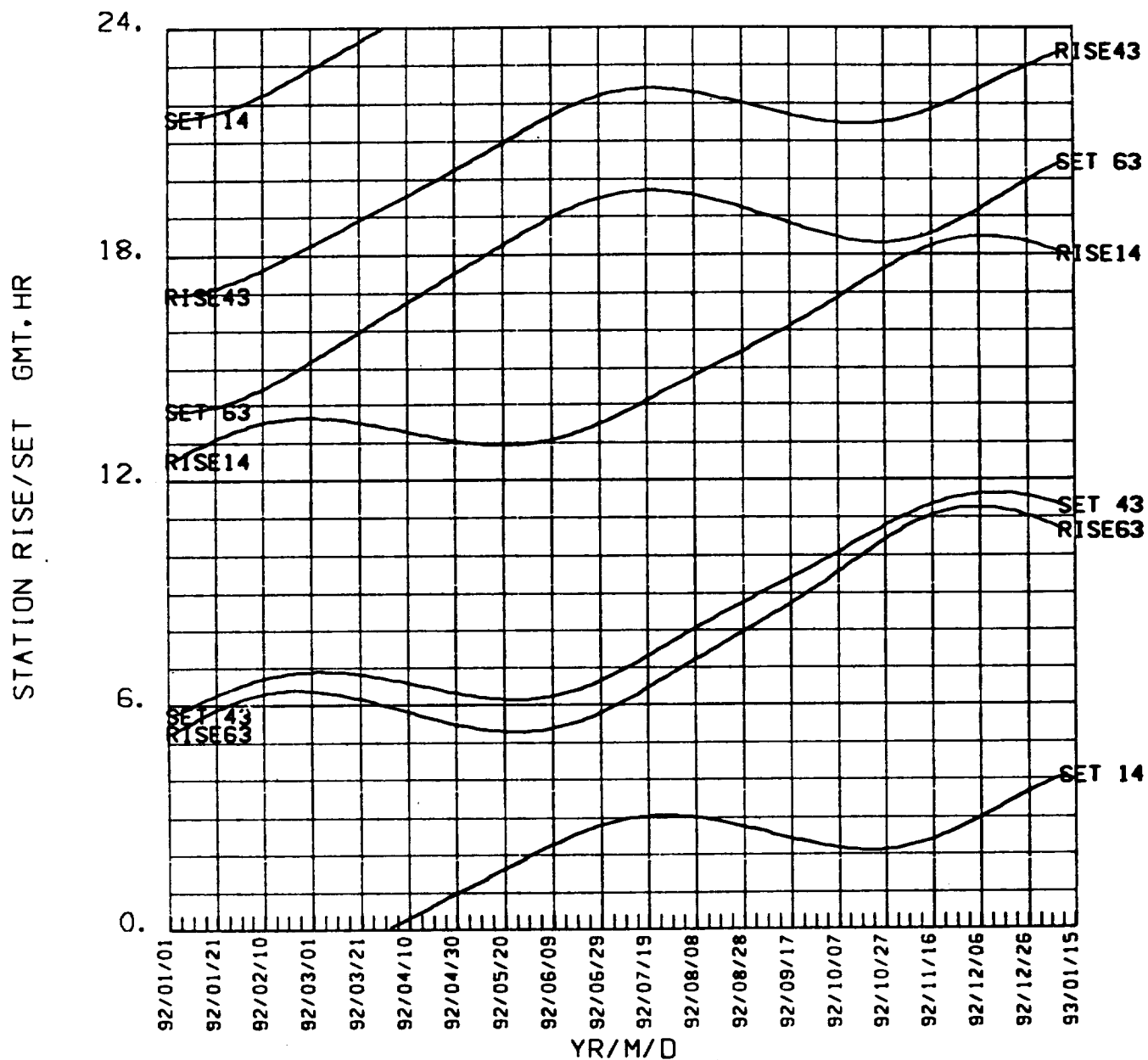
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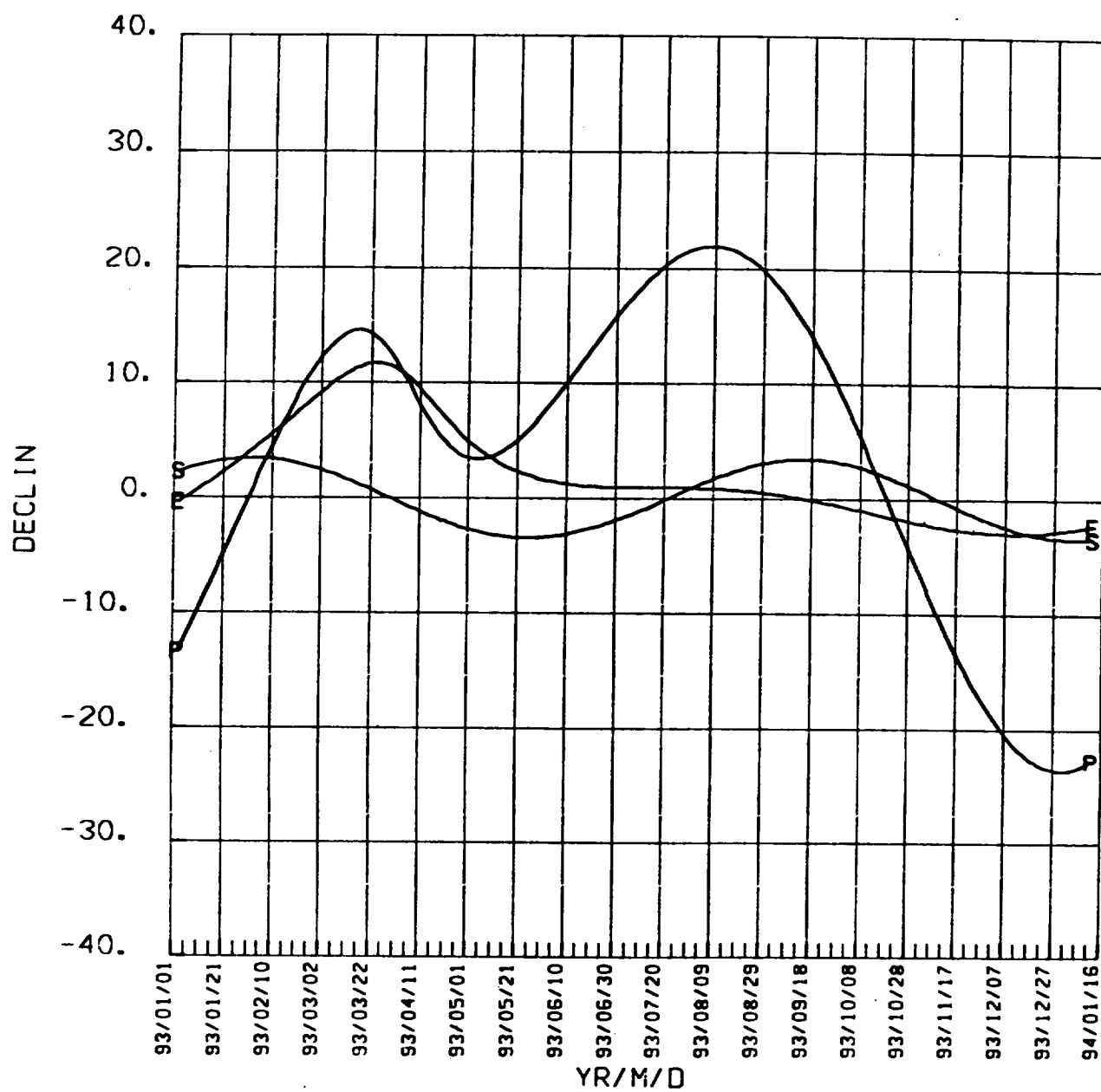


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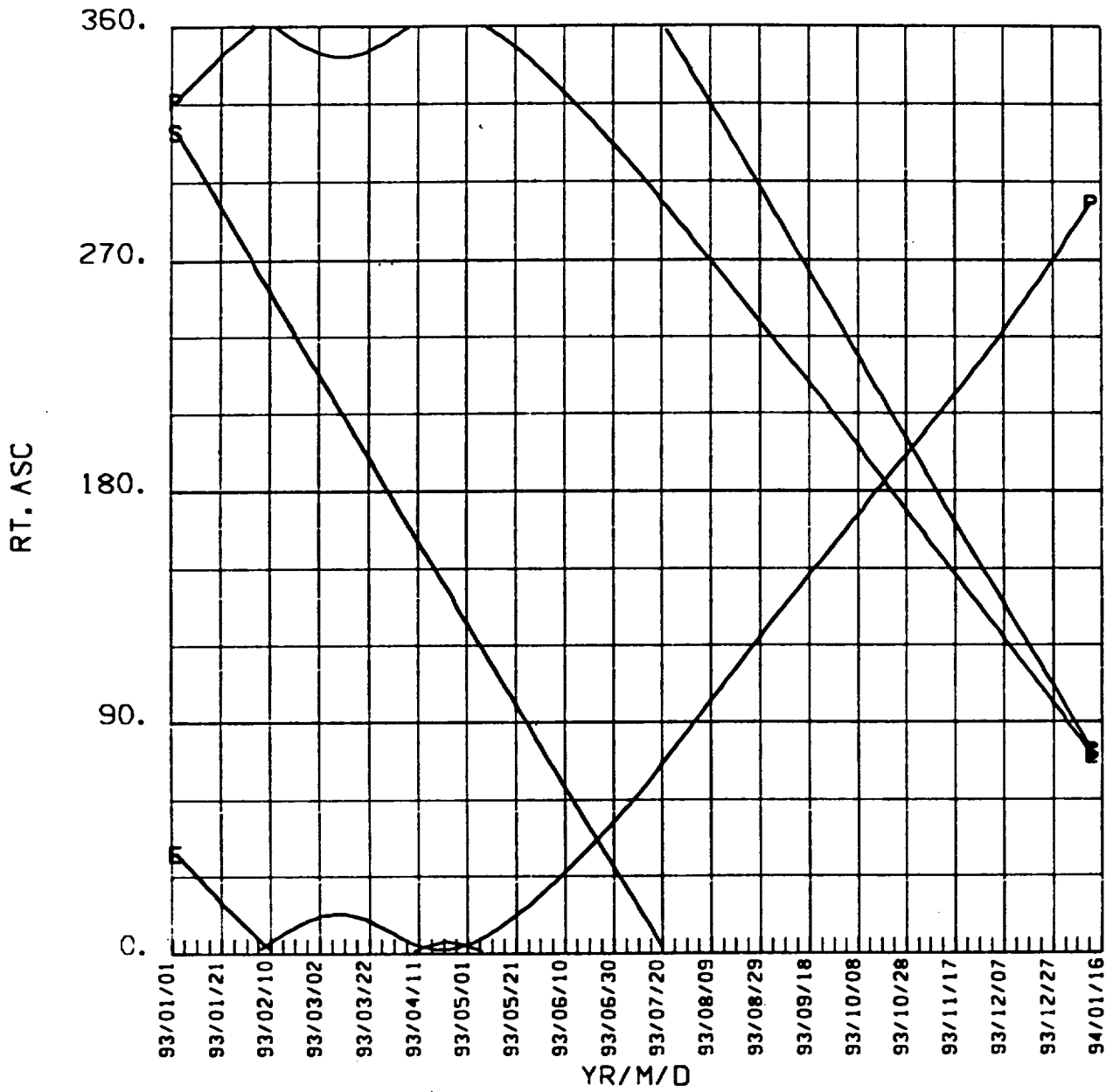
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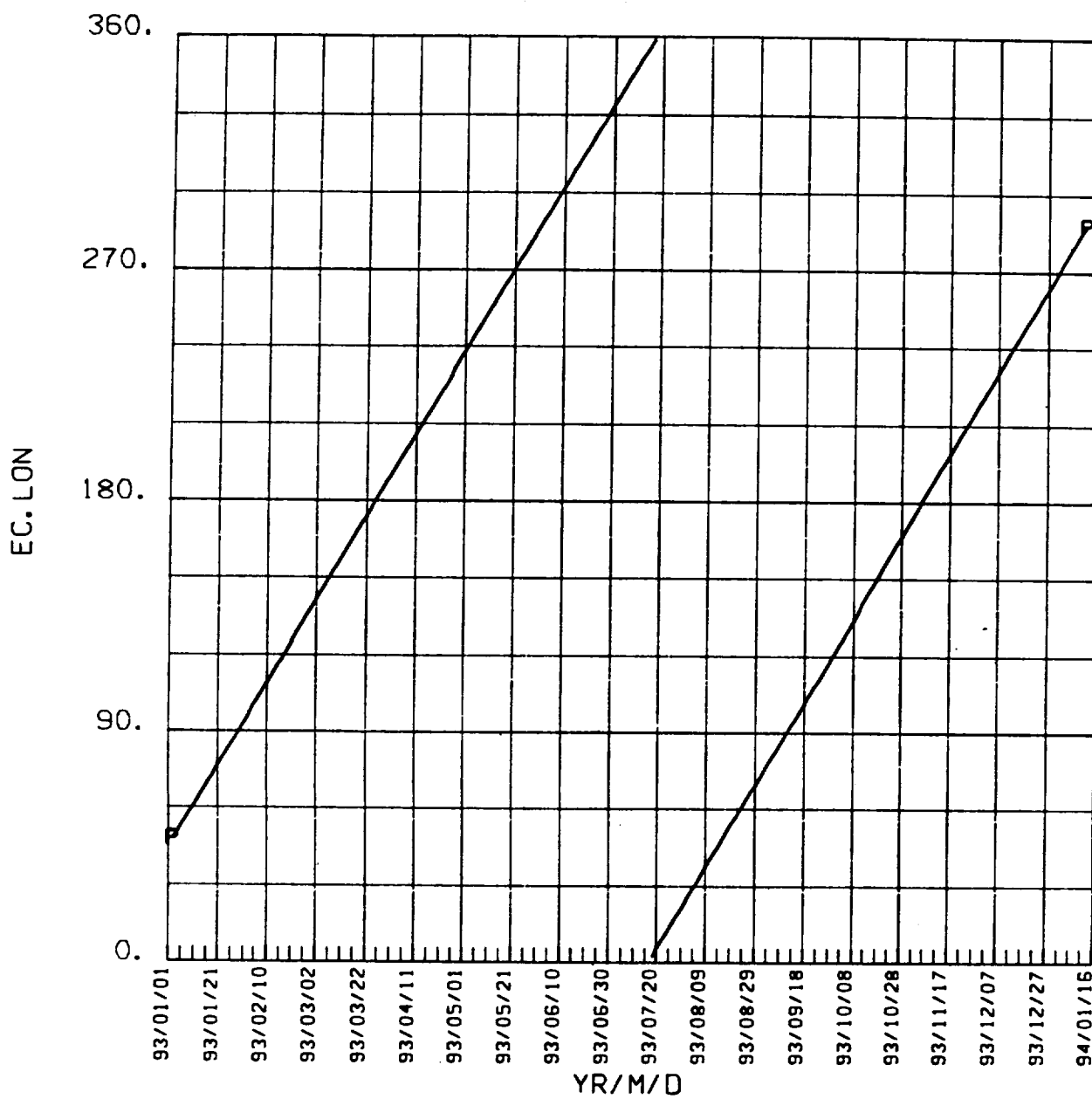
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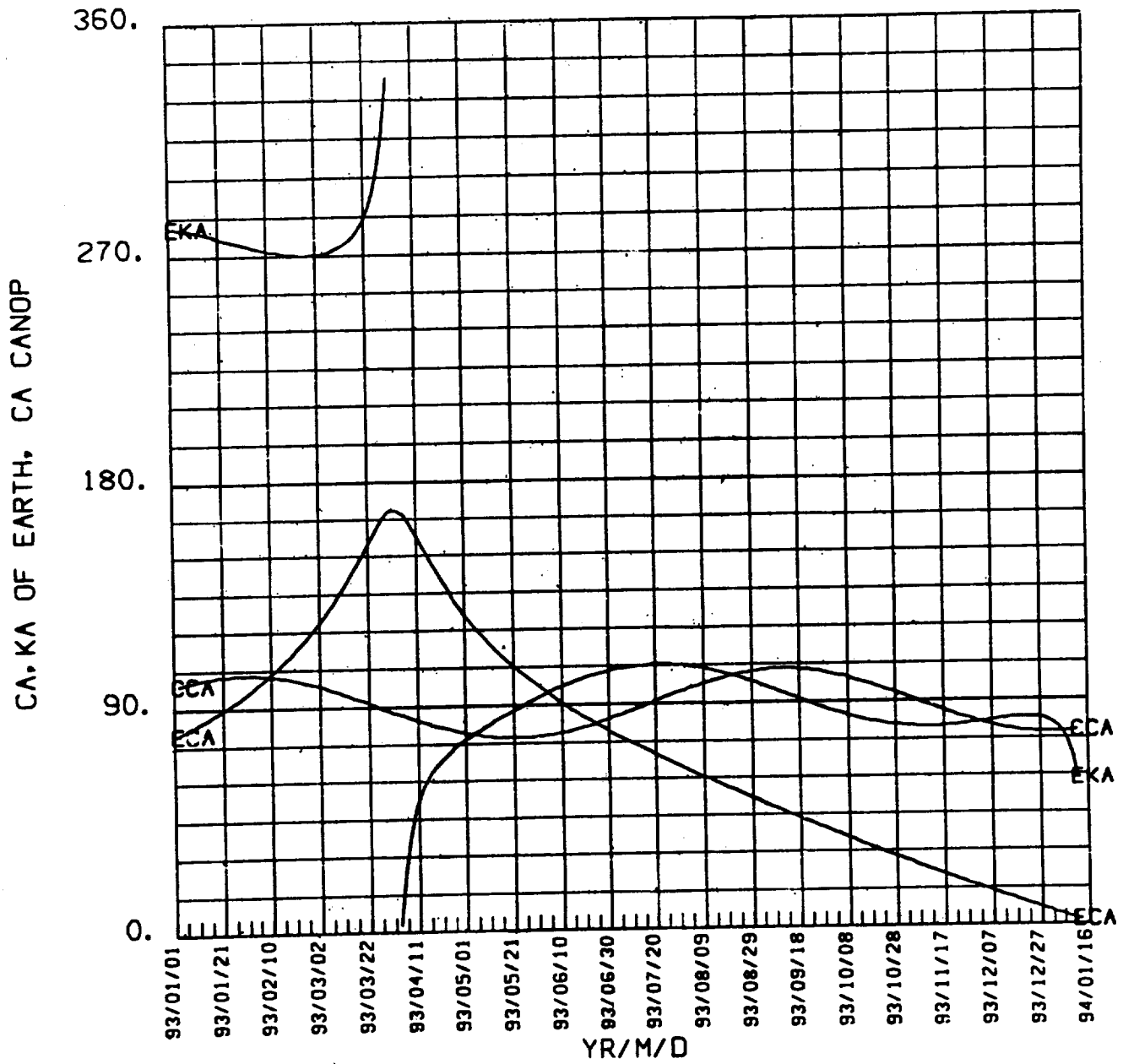
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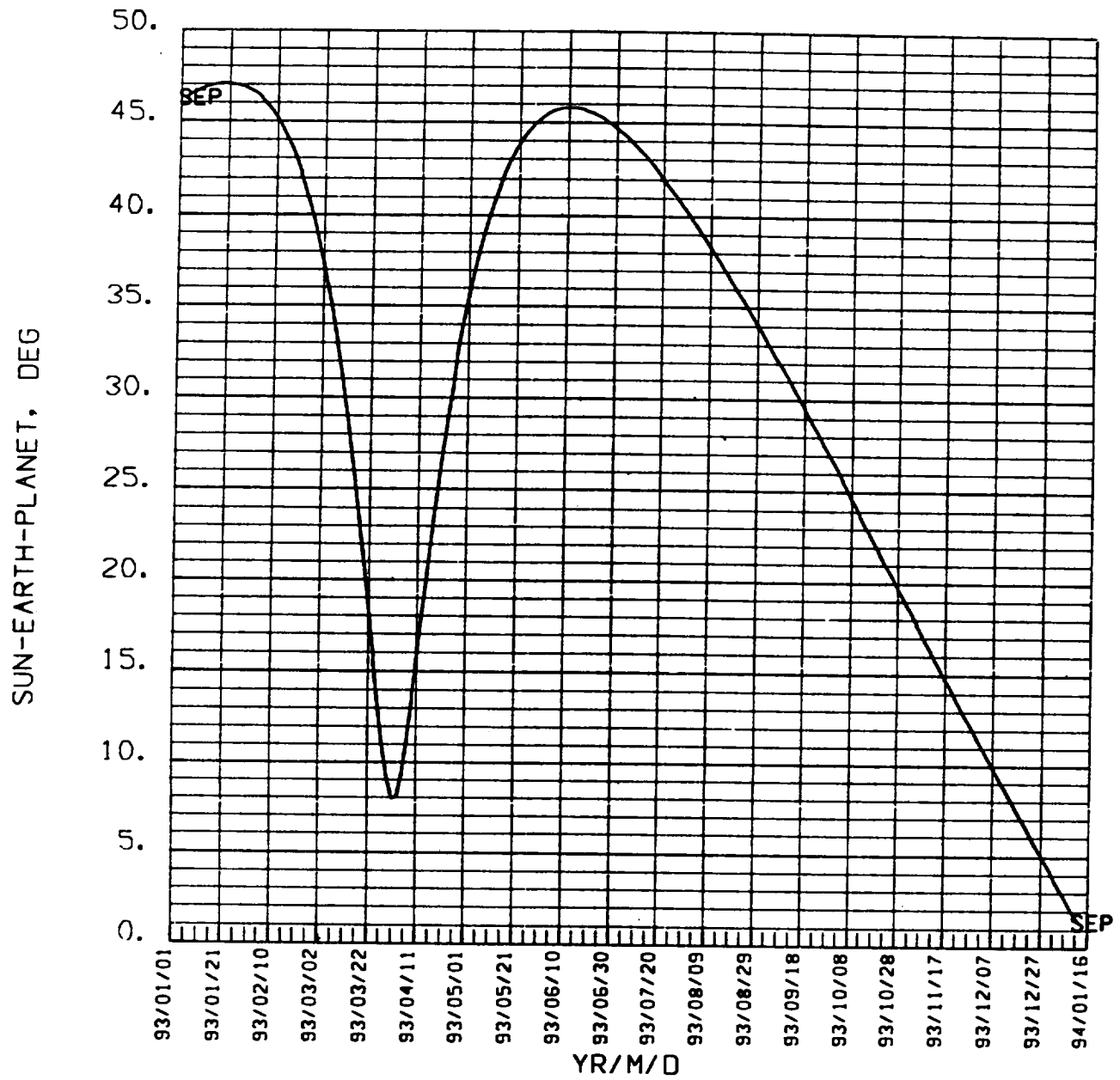
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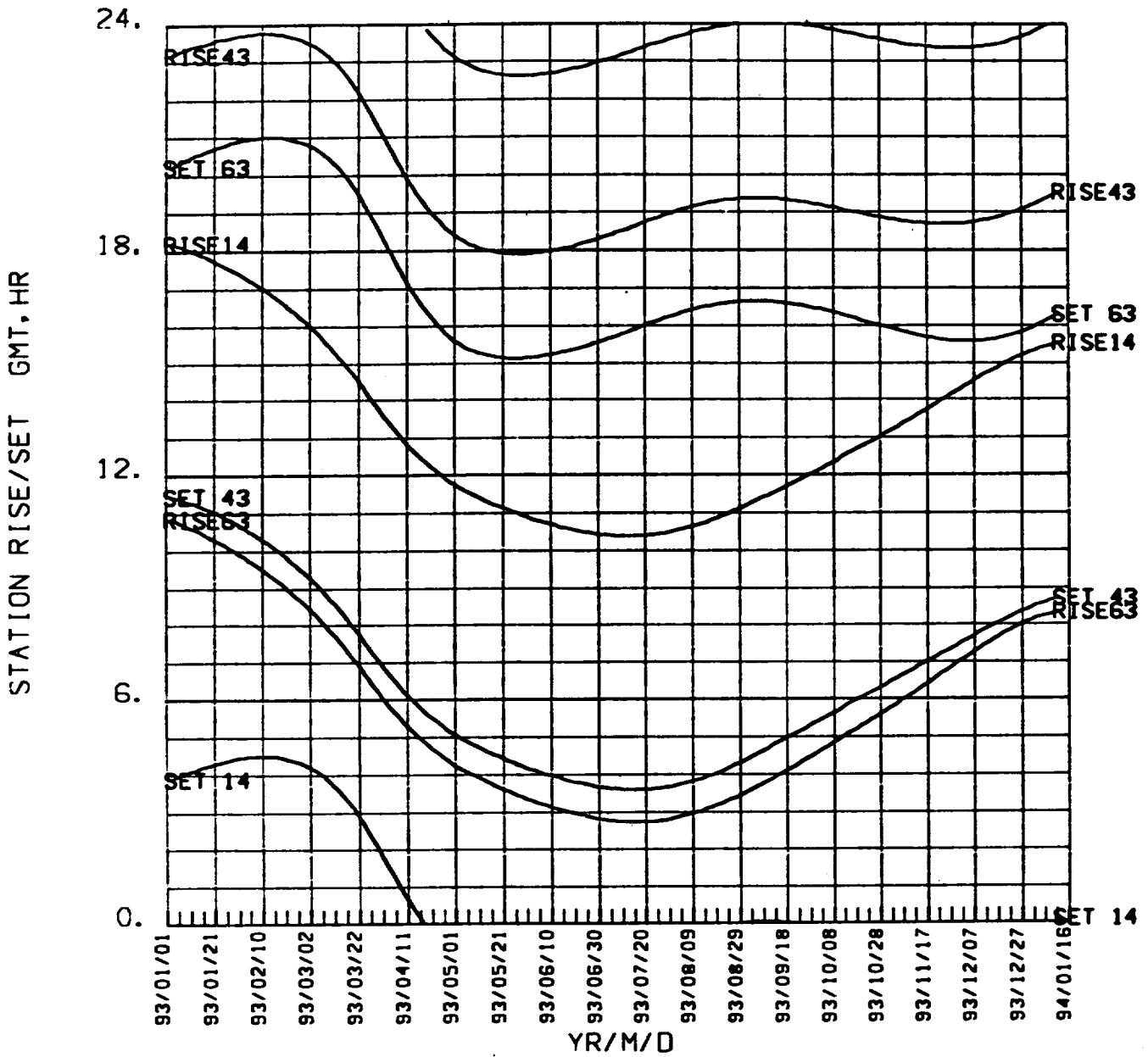


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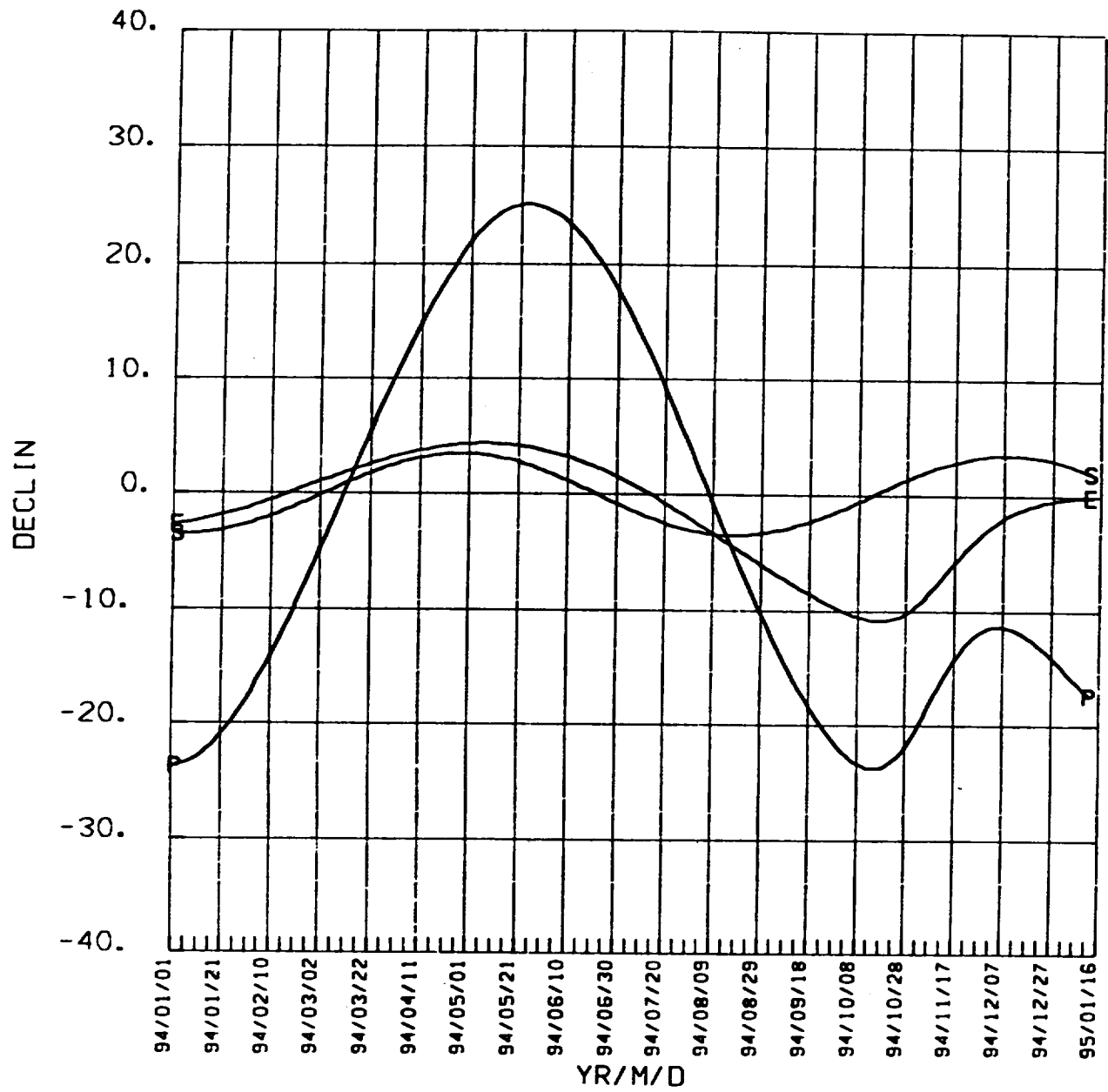


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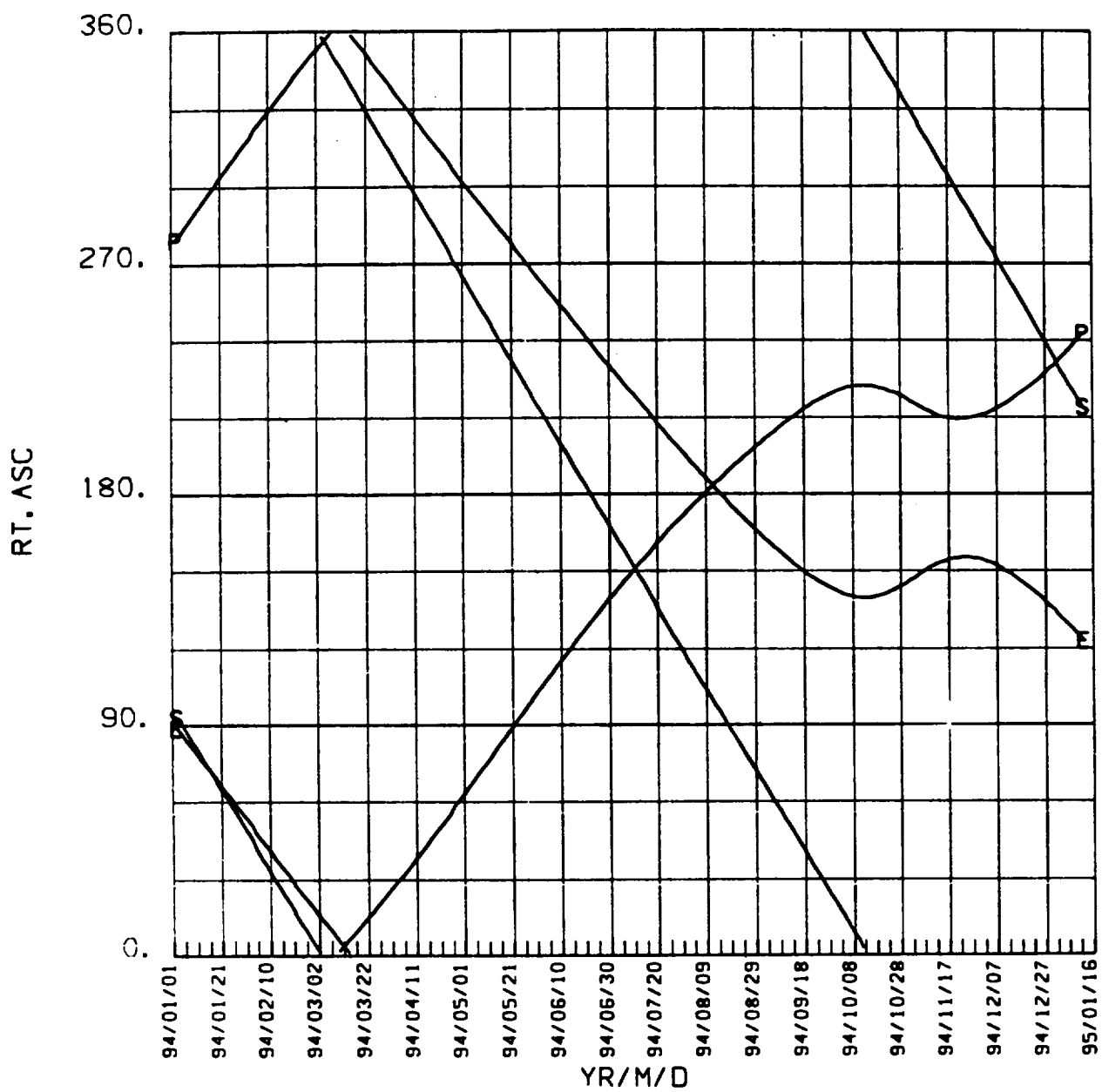
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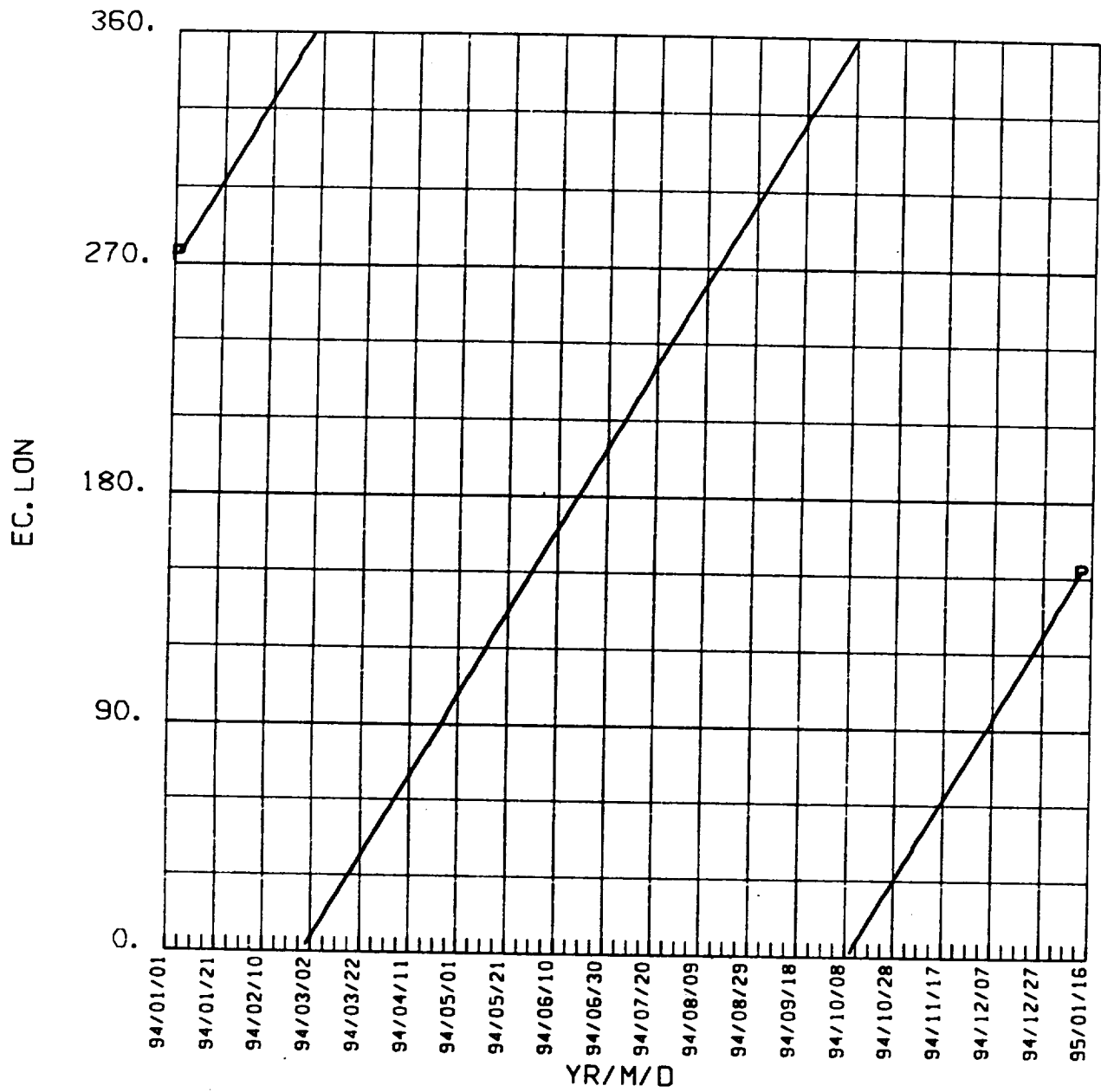
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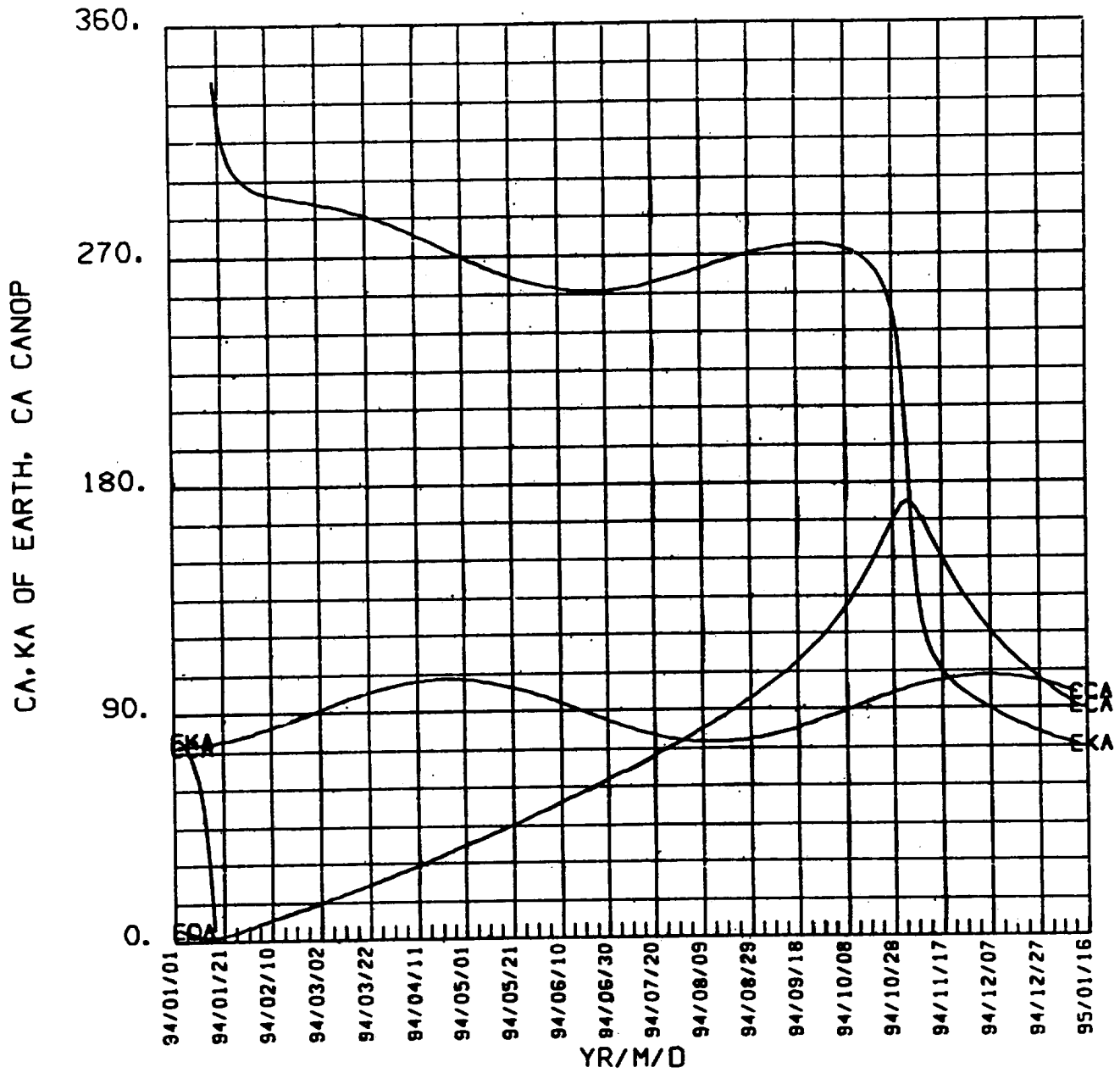
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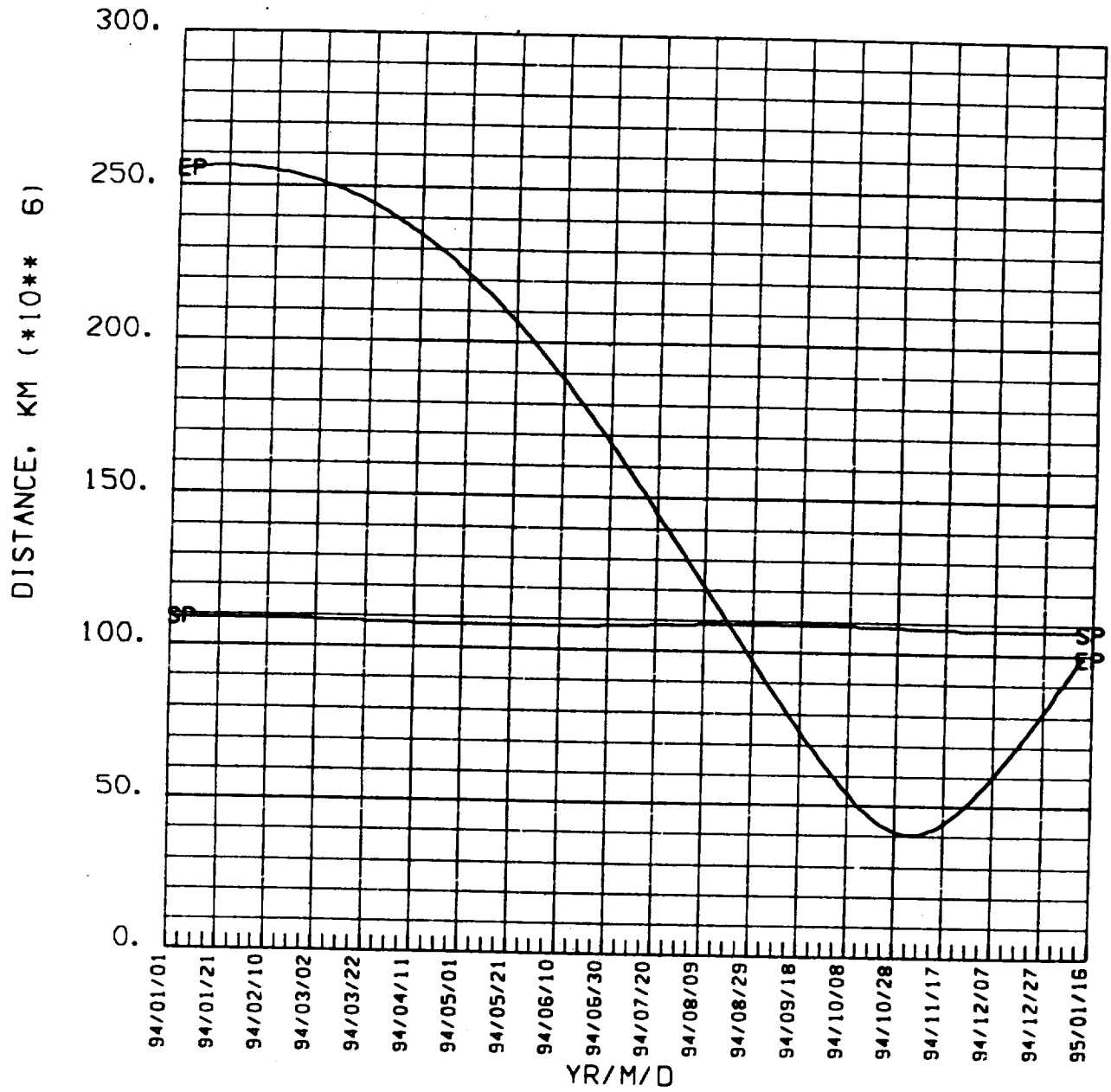
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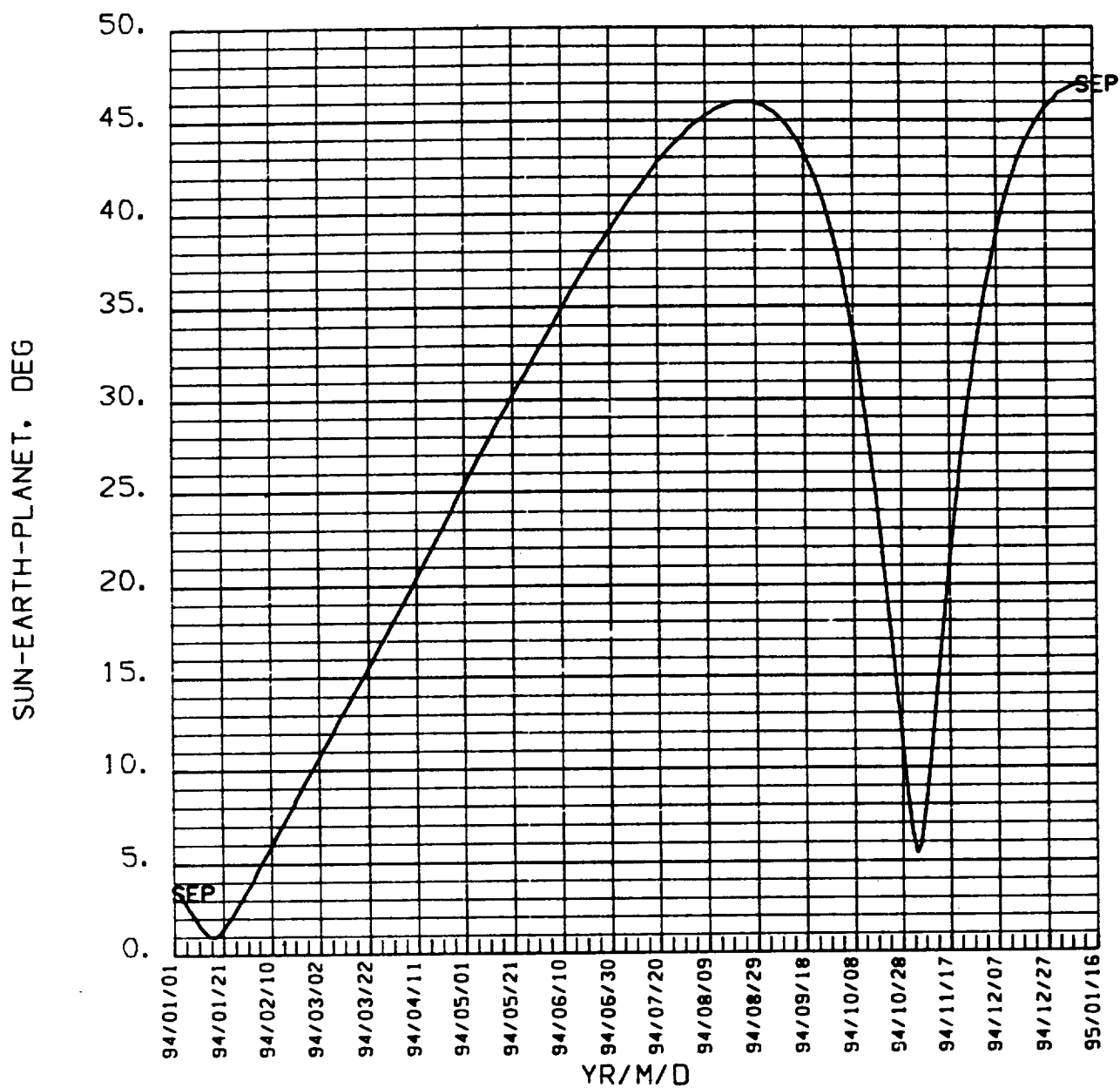


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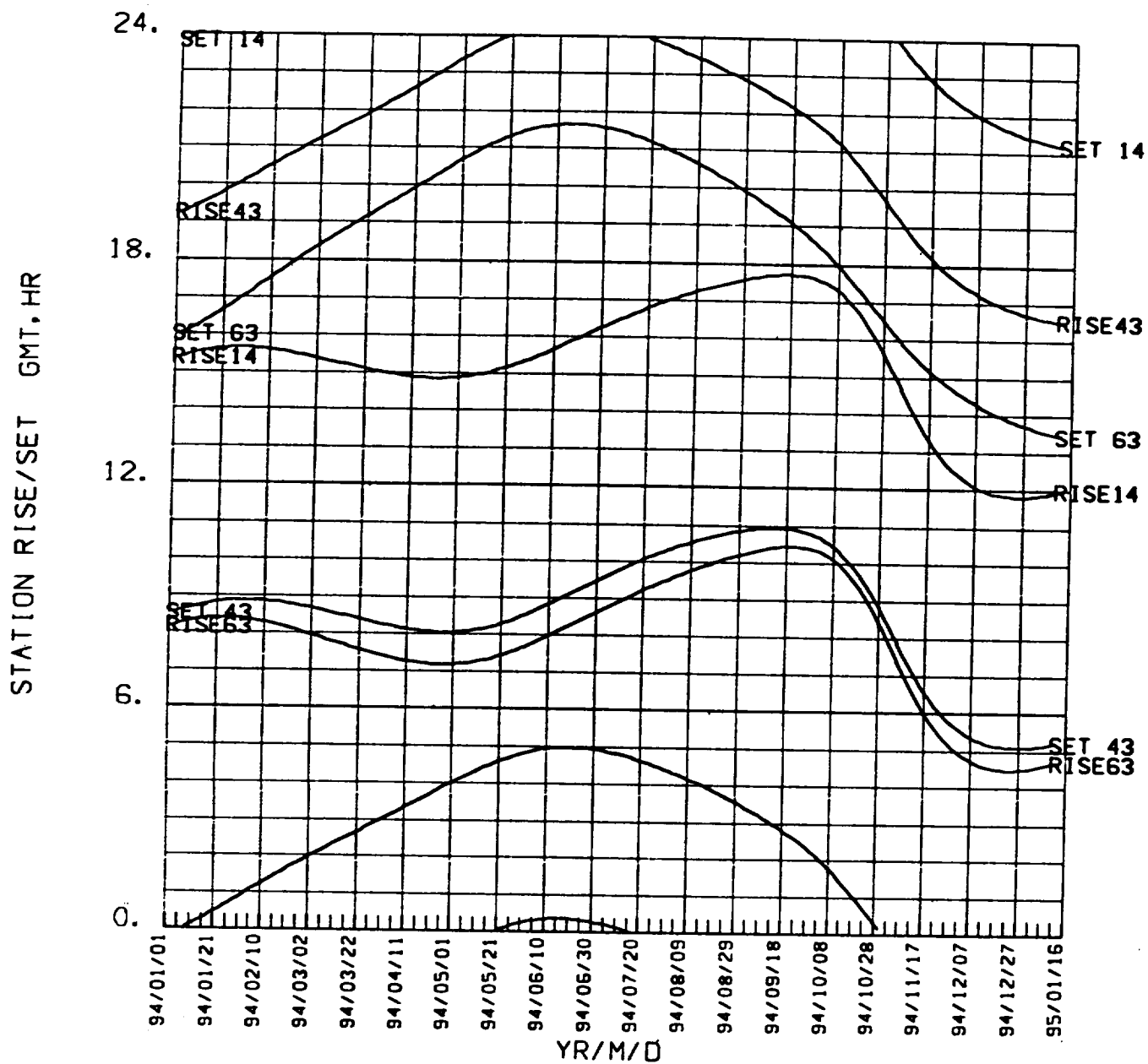


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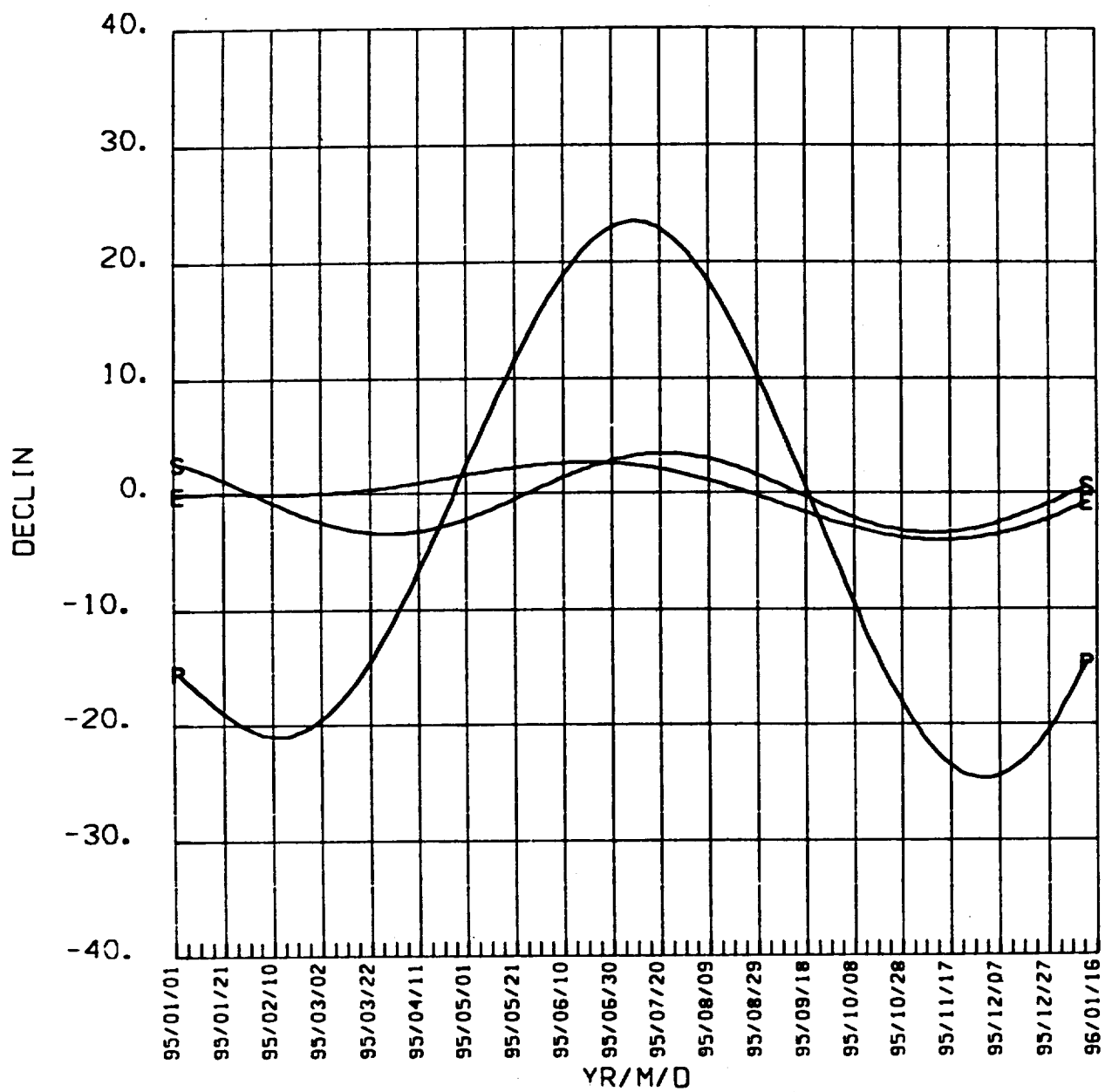
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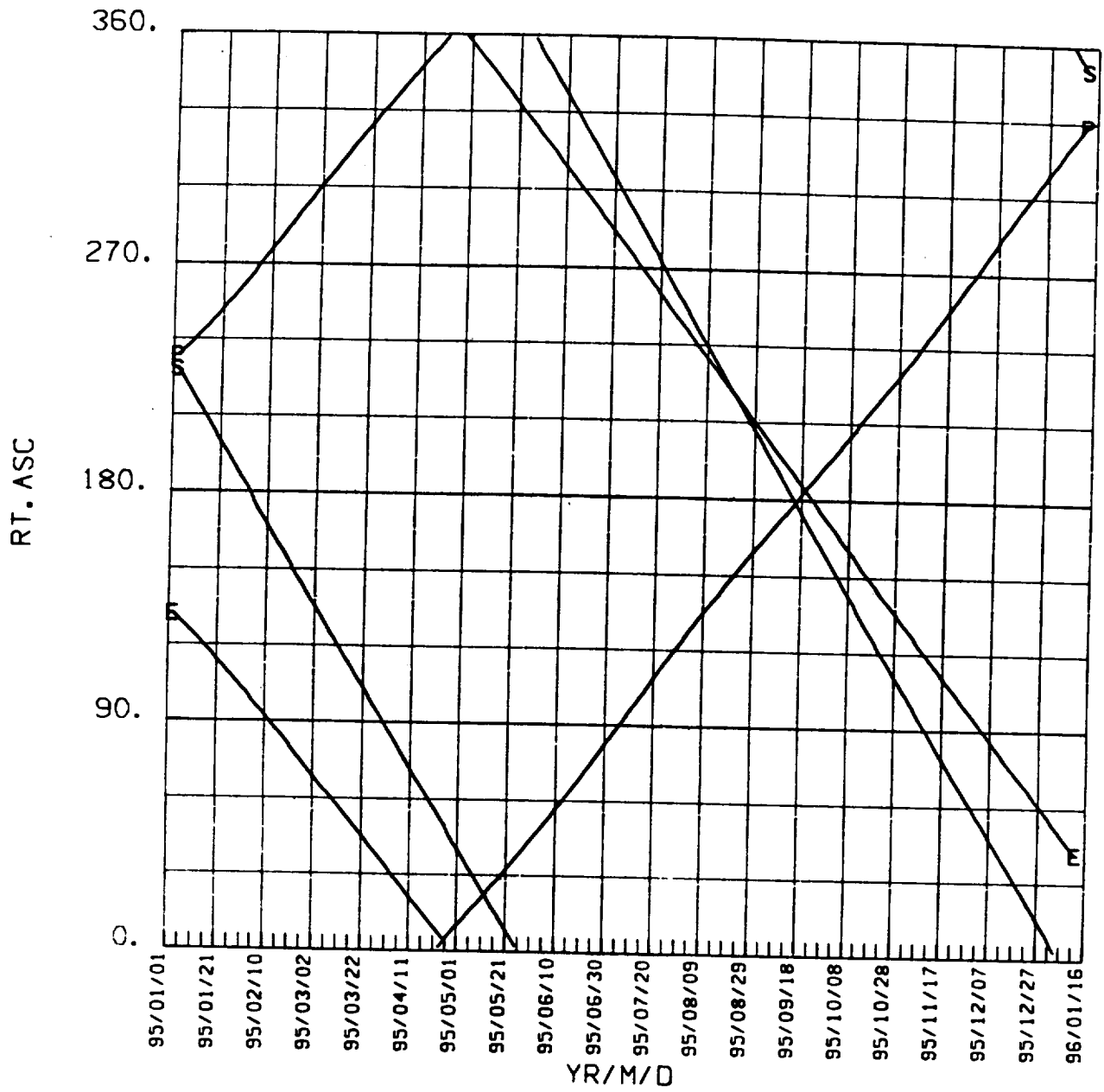
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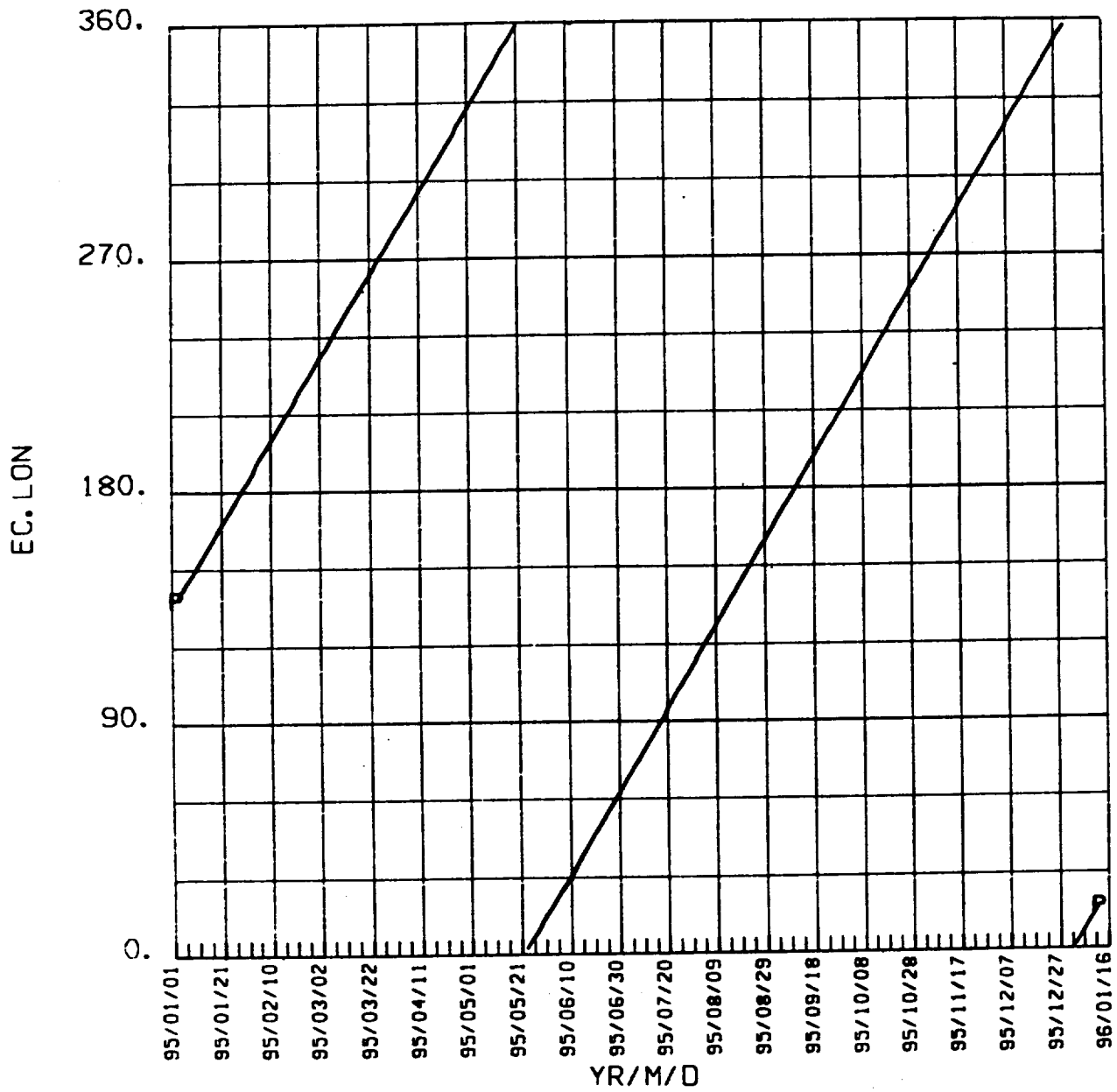
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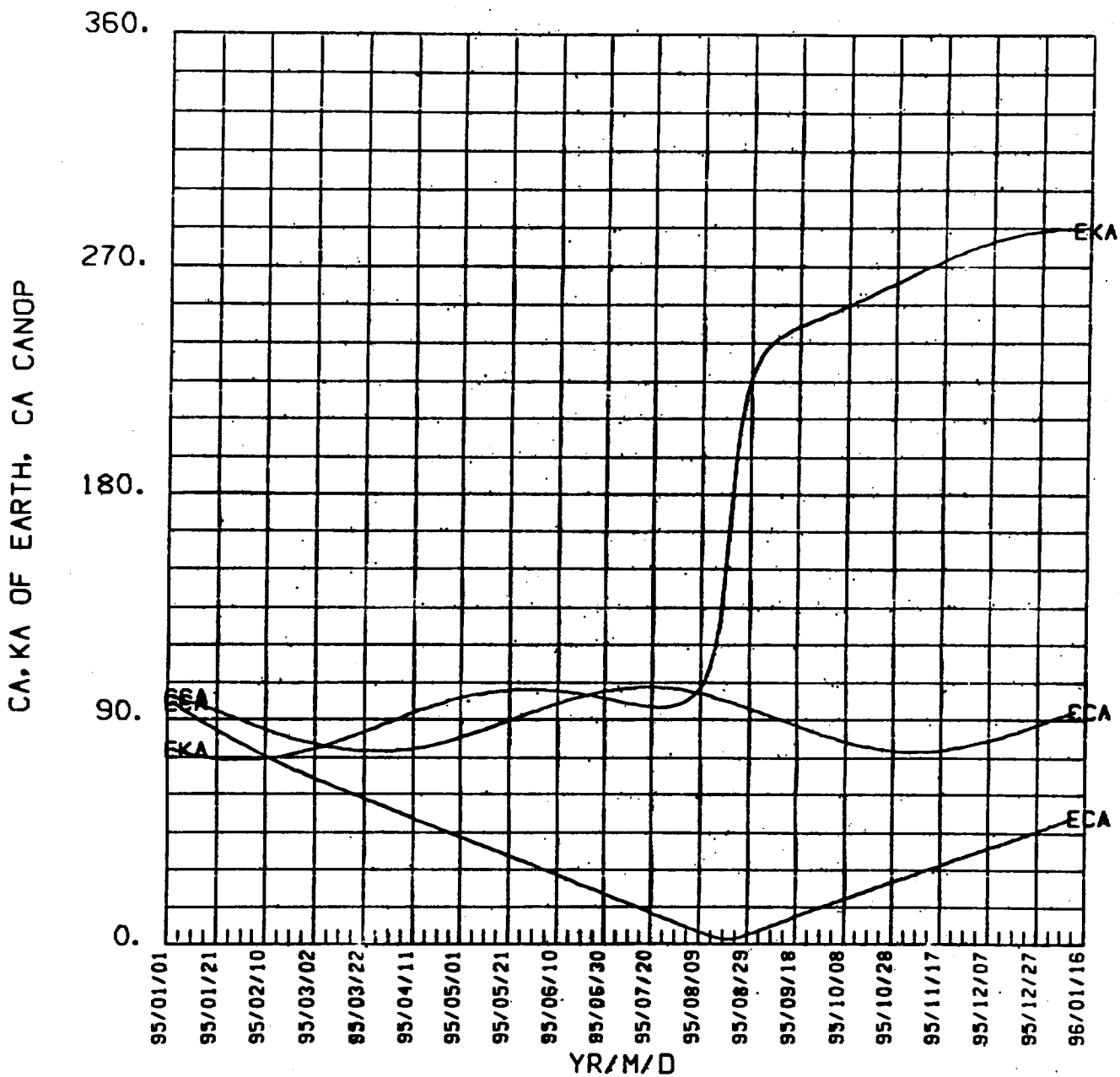
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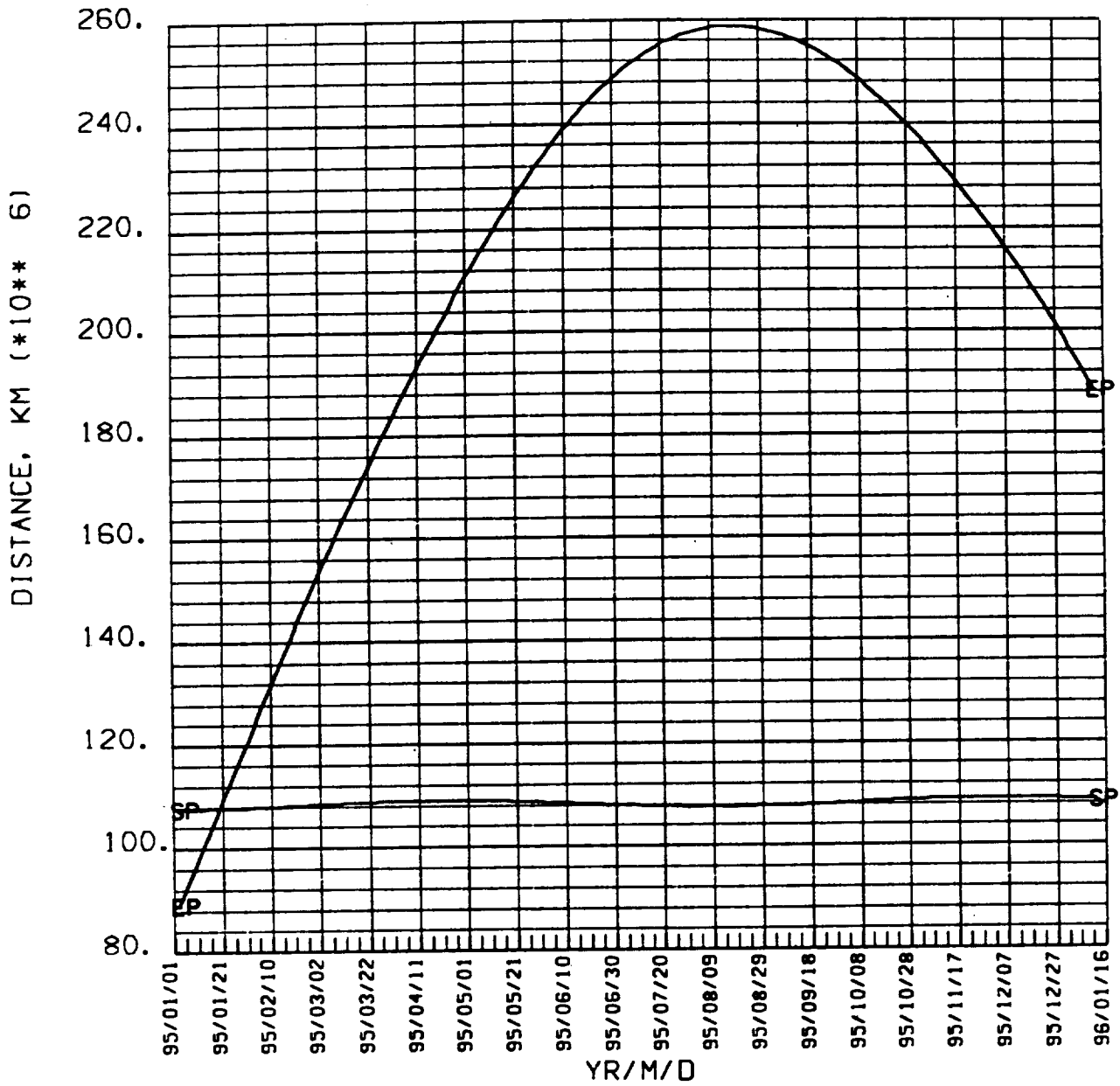
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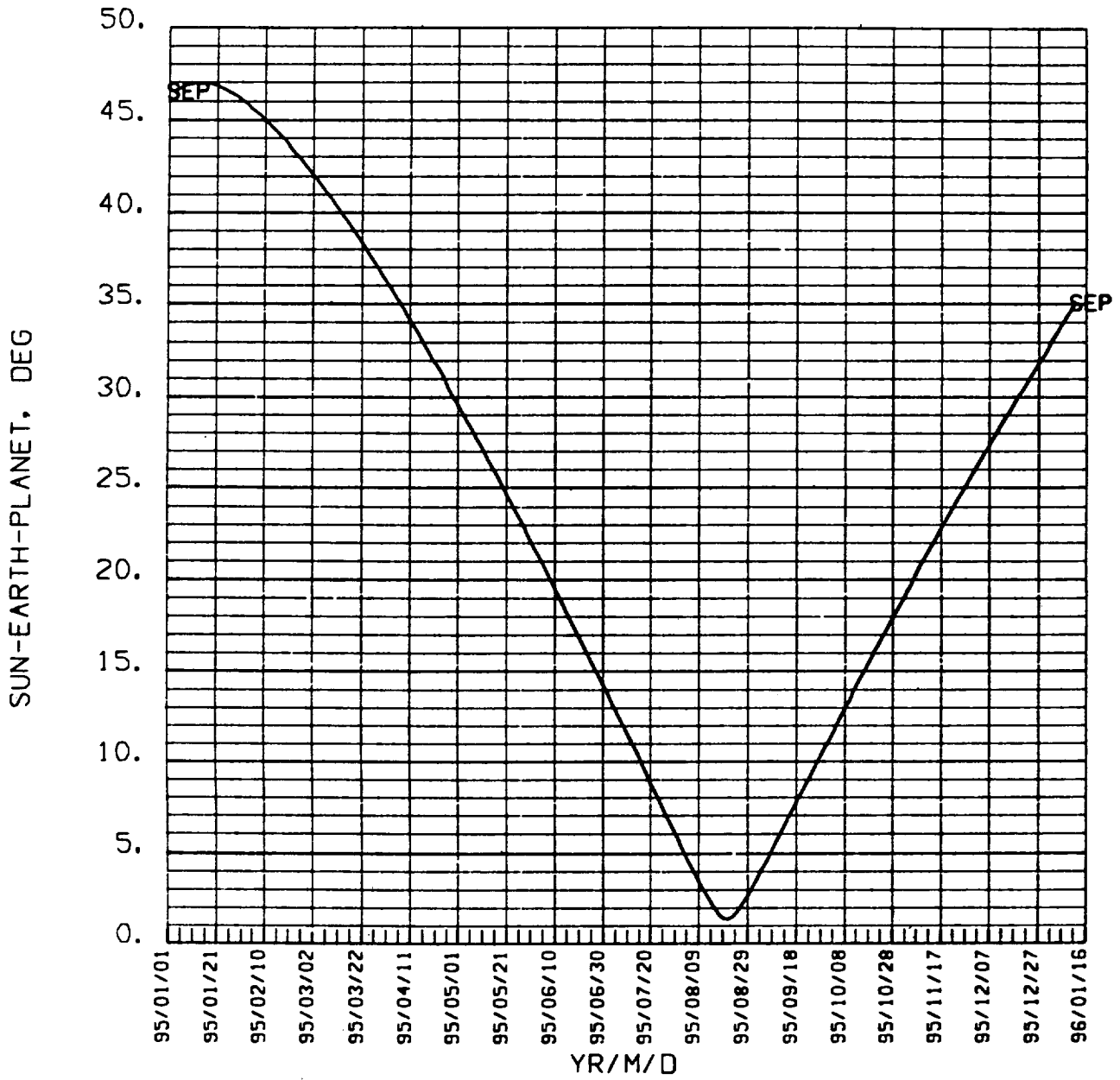
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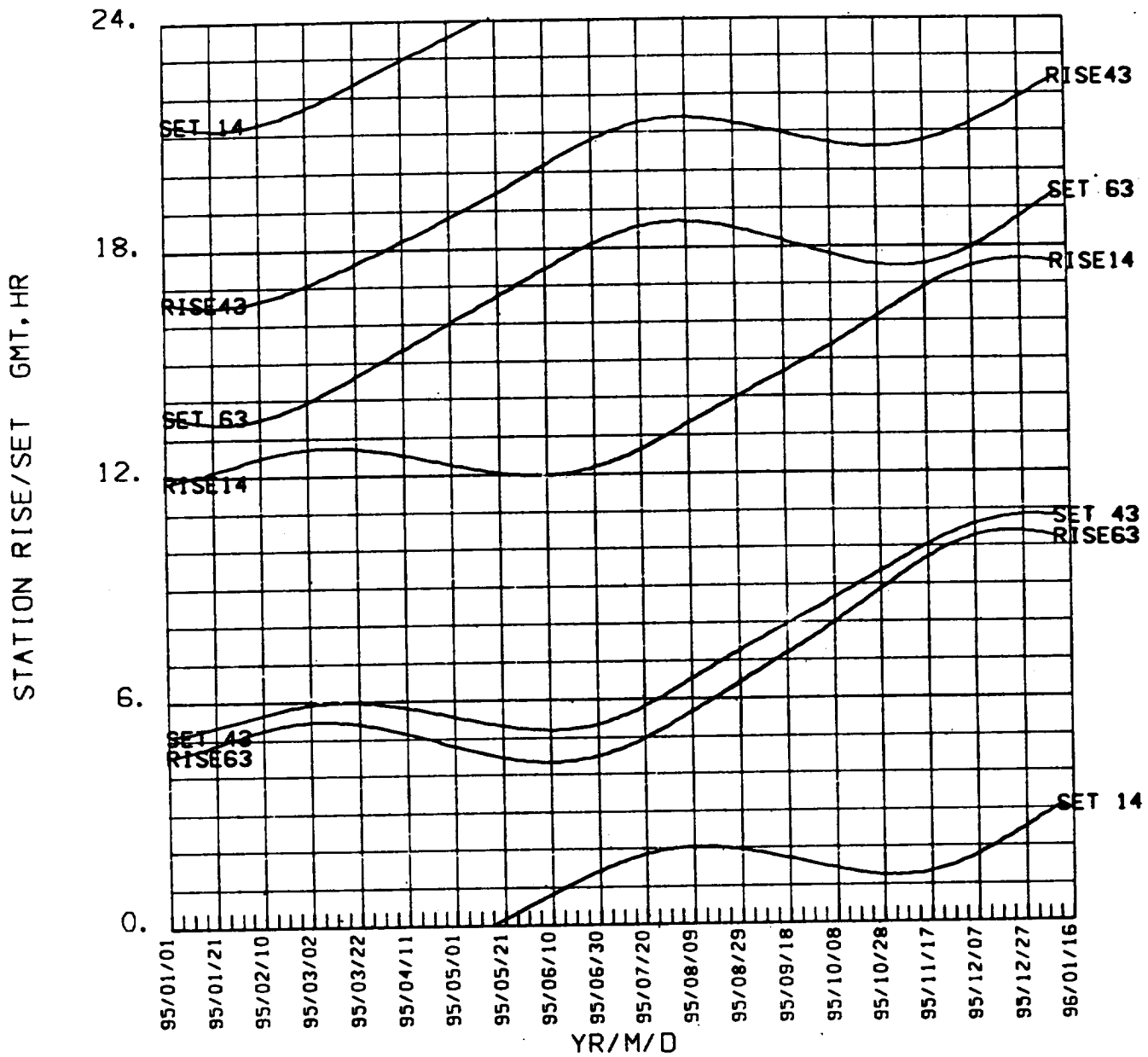


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